Impact of bundled payment system change on average length of stay among surgical patients

- From Diagnosis Related Group to Korean Diagnosis Procedure Combination

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This certifies that the Dissertation thesis of Sung-In Jang is approved.

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ABSTRACT

Impact of bundled payment system change on average length of stay among surgical patients

- From Diagnosis Related Group to Korean Diagnosis Procedure Combination

Background: Since the introduction of the National Health Insurance (NHI) in 1977, Fee-For-Service (FFS) has been the primary payment system for medical services and supplies in Korea. A new payment system, the Diagnosis Related Group (DRG) system, was officially introduced in 2002 for seven principal diagnoses to providers on a voluntary basis. Since July 2012, all public hospitals (39 medical institutions) have been participating in the Korean Diagnosis Procedure Combination (KDPC) payment system for 550 principal DRGs.

Objectives: The purpose of this study was to examine the impact of the change in payment systems from DRG to KDPC on the average length of stay (LOS) for surgical diagnoses. This study aimed to compare these two bundled payment systems and provide evidence for the development of a proper reimbursement system.

Methods: NHI claim data was used. Hospitals that consistently participated in the DRG payment system from January 2007 to June 2012 and the KDPC payment system from July 2012 to June 2014 were defined as case hospitals. Hospitals that consistently participated in the DRG payment system from January 2007 to June 2014 were defined as control hospitals. We conducted 1:2 sampling using the propensity score matching method for age, sex, Charlson Comorbidity Index (CCI), sub-DRG, and admission date (month). A total of 36,240 case admissions and 72,480 control admissions were included in the analysis. Segmented regression analysis of interrupted time series between cases and controls was conducted.

Results: LOS increased by 0.025 days per month ($p = 0.0055$) for three surgical diagnosis-related admissions due to the bundled payment system change. The difference in LOS between cases and controls was not statistically significant 12 and 24 months after the change (12 months: difference = 0.162, $p = 0.4210$; 24 months: difference = 0.465, $p = 0.1052$). LOS among emergency admissions also increased and showed an increasing tendency under the KDRG. For appendectomy admissions (G08), the difference trend in LOS between cases and controls was an increase of 0.015 days per month ($p = 0.0033$) after KDPC implementation compared with before implementation. For hernia procedures, the difference trend in LOS between cases and controls was an increase of 0.040 days per month ($p = 0.0058$) compared with before implementation. For hemorrhoid procedures, no significant change in LOS was observed before and after KDPC implementation. Among high severity cases, LOS significantly increased. Across all admissions, the trend change increased with case severity (CCI 0, 1: 0.022, $p = 0.0142$; CCI 2, 3: 0.026, $p = 0.0288$; CCI $\geq$ 4: 0.055, $p = 0.0003$). For appendectomy admissions, only the CCI $\geq$ 4 subgroup exhibited a statistically significant trend change in LOS between cases and controls (0.077, $p = 0.0044$). For hernia procedures, all CCI subgroups exhibited a statistically significant trend change (CCI 0, 1: 0.033, $p = 0.0361$; CCI 2, 3: 0.049, $p = 0.0045$; CCI $\geq$ 4: 0.043, $p = 0.0379$).

Conclusion: Average LOS for surgical DRG admissions increased following the change in payment system from DRG to KDCP. This LOS increase was observed specifically for complex procedure admissions and high severity cases. Although both payment systems are optimized to

decrease LOS, incentives to reduce LOS are stronger under the DRG system than under the KDPC system. Therefore, these findings suggest that incentives under the DRG lead to excessive LOS decrease in Korea. We suggest that policymakers and stakeholders should focus on the development of an appropriate reimbursement system that focuses on more than cost containment, saving resources, or LOS reduction. More evidence and studies that focus on associations between payment systems and medical outcomes, resource spending, and quality will be needed to achieve this goal.

Key words: Korean Diagnosis Procedure Combination, KDPC, Diagnosis Related Group, DRG, Length of stay, LOS, Payment system, Reimbursement, Bundled payment, Surgical DRG

I. Introduction

It is well known that the system by which purchasers choose to pay providers has a significant impact on the medical decisions and clinical and professional behavior of providers[1-4]. Due to this impact, insurance payment systems have been used to achieve political objectives, such as cost containment and recruitment to underserved areas[5,6]. Since the introduction of the National Health Insurance (NHI) in 1977, Fee-For-Service (FFS) has been the primary payment system for medical services and supplies in Korea[7]. Although the Korean government has regulated some medical costs, including reimbursements to medical suppliers[8], health-related spending has increased consistently and sharply. Both experts and the government have argued that the FFS system, which offers providers autonomy in medical decision-making, is the root of uncontrolled health care costs[3,7-9].

The adoption of a diagnosis-related group (DRG)-based payment system, which is a form of a case-based prospective payment system (PPS) under which payment is based on particular diagnoses for hospital inpatient services[10], was officially proposed by the task force for health care reform in 1994, partly as a political move. Since the implementation of the Medicare inpatient care payment system in the United States in 1983, DRG-based payment systems have emerged as a popular hospital payment system in many European countries and other countries worldwide[11,12]. Compared with the FFS-based payment system, the DRG-based payment system is a supply-side cost-sharing payment system that incentivizes providers to contain medical expenses by introducing economic consequences of health care utilization to the provider[13]. The Korean government accepted and started a pilot project to implement a DRG-based system as a means to contain health care costs in October 1997[7]. The DRG-based payment system was officially introduced in 2002 for seven DRG principal diagnoses, including three principal surgical diagnoses (appendicitis, hernia, and hemorrhoid) on a voluntary basis. The DRG-based payment system has been mandatory for seven principal diagnoses since July

2012, and was expanded to include all medical institutes except long-term care hospitals and public hospitals in July 2013.

Meanwhile, another bundled payment system, the Diagnosis Procedure Combination (DPC), was introduced in 2009. The name of this bundled payment system in Korean means “new DRG”. However, in this study, we have named this bundled payment system the Korean Diagnosis Procedure Combination (KDPC), because this system is very similar to the Japanese DPC. The DPC-based system is a mixed system that includes a flat-rate (i.e., per-case or per-diem) payment and FFS payment, which distinguishes the KDPC from the DRG-based system[14]. The Health Insurance Review and Assessment Service (HIRA), which is a government agency that reviews claims submitted by providers, assesses the quality of care provided, and makes decisions for reimbursement, introduced the KDPC as a payment system for 550 principal diagnoses admissions at all public hospitals in July 2012.

Therefore, three payment systems currently coexist in Korea. The government has set a goal to introduce a bundled payment system as the national basic payment system to contain costs by transitioning risk to the suppliers. This system is also expected to improve administrative conveniences. Suppliers are resistant to a bundled payment system. Furthermore, there is no public consent about the best system. The National Health Insurance council (NHIC), which is the top decision-making body of the NHI contract, suggested a roadmap that would expand a bundled payment system to combine DRG and KDPC. However, although several studies have reported the effect of the payment system change from FFS to DRG[8,10,15-20] and from FFS to KDPC[21,22], no studies have directly compared the DRG-based system with the KDPC-based system. Hence, there exists a need for a more comprehensive comparison and evaluation of these systems to determine which system would be more appropriate in Korea and to inform the overall decision of the NHIC. Therefore, this study analyzed the impact of change from DRG to KDPC with a focus on the average length of stay (LOS). A difference observed between DRG and KDPC may provide important evidence for selecting or developing the next-generation payment system in Korea.

II. Objectives

The purpose of this study was to examine the impact of the change in payment system from DRG to KDPC in Korea on the average LOS for surgical diagnoses.

The detailed objectives of this study were as follows:

(1) To analyze the effect of the change in payment system from DRG to KDPC on average LOS among surgical inpatients by diagnosis, severity, and hospital type at the time of the implemented change.

(2) To analyze the effect of the change in payment system from DRG to KDPC on the change in average LOS by diagnosis, severity, and hospital type.

This study aims to compare two bundled payment systems to provide evidence for the development of an appropriate reimbursement system in Korea.

III. Study Background

1. Health care payment system

A "payment system" is the methodology that a payer uses to compensate one or more providers for care provided to a patient. This system includes definitions of what will and will not be compensated, the ways in which compensation will vary depending on the characteristics of the patient or care provided, and which providers and/or costs will be covered under a single payment[23]. There are seven traditional methods of provider reimbursement that have been utilized within the healthcare system[23,24].

Table 1. Methods of provider reimbursement

Payment method	Explanation
Fee-for-service	A provider is paid a fee for rendering a specific service.
Per diem	A provider is paid a set amount per patient for each day that patient is in the provider's care. All services rendered during that day are covered under the set amount.
Case payment (DRG)	A single provider is paid a set amount for all services rendered (by that provider) during a admission of care.
Episode-of-care	A single provider is paid a set amount for all services rendered (by that provider) during a defined "episode" of care. For example, a provider may be paid a pre-determined amount for a patient undergoing a kidney transplant. This payment would cover the surgery and all services, including follow-up, associated with that "episode." Using this method there would typically be multiple payments for a single episode since more than one provider may treat a patient.
Multi-provider bundled episode-of-care	Multiple providers are jointly paid for all services rendered during an episode of care, as defined above. Using this method there would only be a single payment made by the payer, which would cover the services rendered by all providers.
Condition-specific capitation	One or more providers are paid a pre-determined fee to cover all services rendered for a specific condition. These payments can be either a onetime fee or on going depending on the severity of the illness.
Capitation	One or more providers are paid a regular, pre-determined fee to cover all services rendered for the continuous care of a patient. This fee covers all episodes and all conditions.

There is no perfect payment method. Each type of provider reimbursement method carries its own set of risks. Those risks are assumed either by the payer, the provider, or both. Generally speaking, as you move down the payment type list from FFS to capitation, the risk shifts from payer to provider[24]

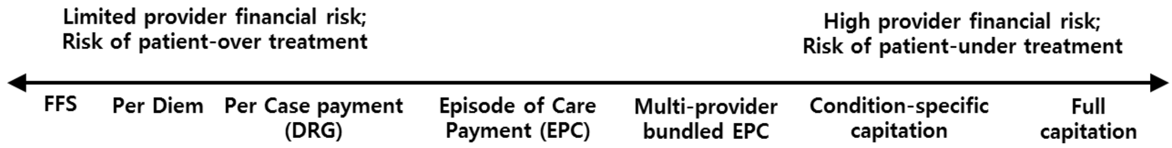

Figure 1. Continuum of health care payment methods (modified Miller, 2007; Nicole, 2008)

According to Miller, different methods of payment assign different levels of risk to either the payer or provider (Figure 2). FFS systems tend to provide financial incentives for providers to overtreat the patient. Under an FFS system, the payer assumes the full risk of care; the payer can pay or choose not to pay for as many services as the provider is willing to render. Under an episode-of-care system, the provider assumes slightly more risk because it is unknown at the beginning of the "episode" what services may be needed. Condition-specific capitation incentivizes the provider to limit the number of "episodes" of care per condition. Full capitation incentivizes the provider to prevent illness in the patient and to treat any illness in an efficient manner. However, full capitation is also more risky to providers that treat sicker-than-average populations. Essentially, payment methods that include any kind of bundling or capitation create a financial risk for providers, which may cause them to undertreat their patients. In contrast, payment methods that individualize services and their associated payments (e.g., FFS) put patients at risk of overtreatment.

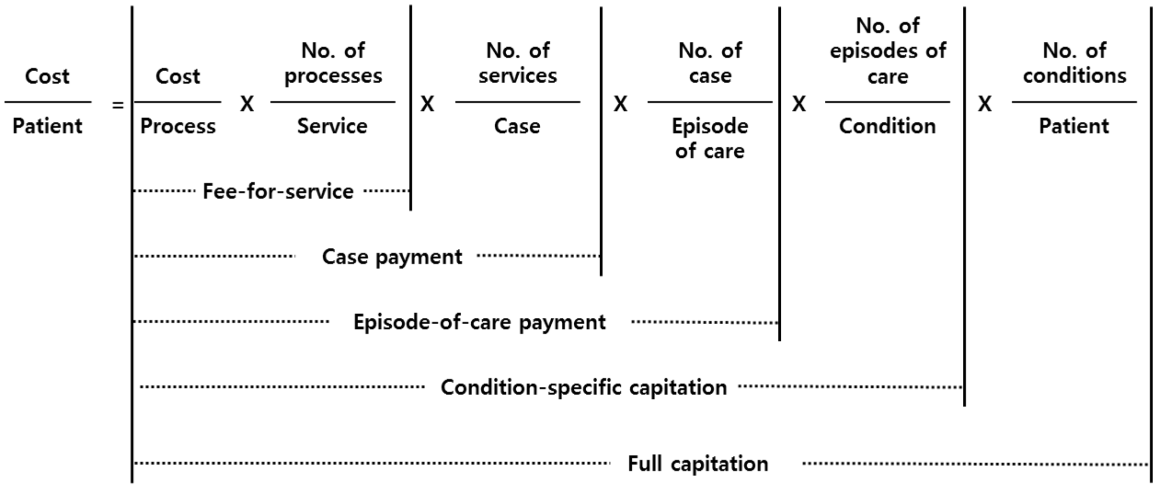

Figure 2. Variables for Which the Provider is at Risk Under Alternative Payment System (modified Miller, 2007)

2. Previous studies of the impact of payment system changes on LOS

Many countries have recently introduced new payment systems or implemented a change in payment systems, primarily for financial reasons. Many countries have changed from a traditional payment system to a DRG/PPS payment system. Previous studies on the effect of payment method changes on LOS are shown in Table 2. LOS is a representative index for the evaluation of the impact of a payment change in these studies, because LOS is easy to estimate and directly correlates with resource spending.

Many studies have explored the introduction of DRG to the United States in 1983[25-29]. According to Ellis et al., average LOS decreased by 4.5 days due to a payment system change from Retrospective and procedural reimbursement to DRG, 1.8 days of which were attributed to a moral hazard effect, and -3.0 days of which were attributed to what we have called a practice-style effect[26]. In another study on the impact of change from a cost-based reimbursement method to a per-diem method and per-case prospective payment method, approximately 85% of per-diem patients were discharged by the 25th day since admission compared with 79% of cost-based payment patients (and 86% of per-case payment patients)[27]. Freimen et al. further showed that a decrease in LOS due to the payment system change from Retrospective and procedural reimbursement to DRG was observed in for-profit hospitals but not in non-profit hospitals[28]. Marjorie et al. also reported a decrease in LOS in community hospitals[29].

The impact of a payment system change from FFS to DRG has also been studied in other countries. In Taiwan, a 10% decrease in LOS of coronary artery patients was observed[30]. Similarly, in Switzerland, LOS was decreased by 1.9 days[31]. In China, in one study, the growth rate in LOS was reported to be 13.1% and 13.0% points lower in diseases covered by the DRG than diseases not paid by the DRG in 2004 and 2005, respectively[32], but another study reported contradictory results[33].

In Israel and Austria, the payment system method changed from a per-diem method to a DRG-based payment method. According to Shmueli et al., LOS among patients who underwent surgical procedures decreased by 5.6-21.7% in Israel[34]. In Austria, average LOS decreased by 0.493 days[35].

Several reports have examined the impact of the change in payment method to a smaller payment unit. Hersen et al. showed that average LOS decreased in response to a change from a budgeting system to a DRG system in Germany[36]. Similarly, in Italy, average LOS decreased from 9.1 days to 8.8 days, resulting in a 21.1 percent decrease in hospital bed days ($p < 0.001$), following a change from a global budgeting payment system to a DRG-based system[37]. Average LOS also decreased from 11.78 to 8.99 days (-2.78 days) in Hungary after the payment method changed from a hospital budget to a DRG-based system[38].

The DPC-based system was introduced in Japan in 2003. Before the introduction of DPC, FFS was the traditional payment method. In addition, a pilot implementation of DRG/PPS was applied in 1998. According to both Okamura et al. and Wang et al., average LOS has decreased by 4.5% in Japan under the DPC-based payment system[39,40]. However, because DRG/PPS was not implemented over a long time period, it is hard to find studies which have compared the impact of DRG and DPC on LOS.

Table 2. Previous studies about the effect of payment method change on LOS

Study	Payment method change from	Payment method change to	Result about LOS	Year
DesHarnais SI et al.	Retrospective and procedural reimbursement	DRG/PPS	Average length of stay decreased, especially for patients treated in scatter beds.	1990
Ellis RP et al.	Retrospective and procedural reimbursement	DRG/PPS	4.5 day reduction in LOS (14%) . 1.8 days of this change can be attributed to a pure moral hazard effect, and -3.0 days to what we have called the practice-style effect. The overall population may be getting slightly sicker, increasing average LOS by + 0.3 days.	1996
Frank RG et al.	Cost-based reimbursement	Per diem rates	85% of the per diem payment patients have been discharged by the 25th day compare with79% for cost-based payment patient.	1989
		Per case prospective payment	86% of the per case payment patients have been discharged by the 25th day compare with79% for cost-based payment patient.	
Freimen MP et al.	Retrospective and procedural reimbursement	DRG/PPS	Not-for-profit hospitals experienced declines in lengths of stay averaging between 10% and 20% two years after they went onto PPS, while for-profit hospitals experienced a somewhat greater decline.	1989
Marjorie A. Rosenberg et al.	FFS	DRG/PPS	Average length of stay fell 9%. In 1995, average length of stay was 7.1 days. Average length of stay at national community hospitals declined from 7.7 days per stay in 1975 to 6.5 in 1995.	2001
Cheng et al.	FFS	DRG/PPS	10% decrease (p<0.001) in patient's length of stay of coronary artery patient in Taiwan.	2012
P. Schuetz et al.	FFS	DRG/PPS	LOS in DRG hospitals was significantly shorter compared to FFS hospitals (8.4 vs 10.3 days, absolute difference 1.9 days in Switzerland.	2011
Yip W et al.	FFS	DRG/PPS	Did not decrease LOS (+0.70day) in China.	2001
Jiale Zhang	FFS	DRG/PPS	The growth rates of LOS were 13.1 and 13.0 percentage points lower than that of other diseases during the 2004 and 2005 experiments, respectively.	2010
Shmueli A et al.	Per-diem	DRG/PPS	Surgery procedure LOS decreased -5.6~-21.7% in Israel.	2002
E. Theurl et al.	Per diem	Per case-based	Impact on average LOS is -0.493 days in Austria.	2007
P. Hensen et al	budgeting system	DRG/PPS	The average LOS has been continually reduced in Germany.	2007
D.Z. Louis et al.	Global budgeting	DRG/PPS	The mean length of stay decreased from 9.1 days to 8.8 days, resulting in a 21.1 percent decrease in hospital bed days (p < .001), in Italy.	1999
M. Kroneman et al.	Hospital budget	DRG/PPS	The average LOS decreased from 11.78 to 8.99 (-2.78) in Hungary.	2001
Wang K et al.	FFS	DPC	The ALOS is significantly reduced.	2010
Okamura et al.	FFS	DPC	ALOS has shown a 4.5% decline at the special functioning hospitals under the DPC payment system, whereas a 1.5% decline has been seen at all medical hospitals under the conventional fee-for-service payment system in April–October 2002 when compared with the same term in 2003.	2005

3. The Bundled Payment System in Korea

The bundled payment system is a general term of paying system which is bundling a payment unit in particular level. And it could be classified according to payment unit, as follow[41](table 3).

Table 3 Classification of bundled payment

	Per outpatient visit	Per admission day	Per admission	Per episode
Physician	OPPS			
Hospital		per diem	DRG	
Physician and Hospital		DPC KDPC		per episode

*OPPS: Outpatient prospective payment system; DPC: Diagnosis procedure combination; KDPC: Korea diagnosis procedure combination; DRG: Diagnosis related group
*Source of Park et al.[26])

An outpatient prospective payment system (OPPS) was implemented to reimburse outpatient visits for Medicare beneficiaries in the United States in 2000[29]. OPPS is a bundled payment system in which payments are paid per outpatient visit[22,42,43]. The Korean version of the OPPS, the Ambulatory Patient Group (APG), was developed in 2006 but has not been implemented[43]. According to Averill et al., an episode payment would encompass services delivered not only during the hospitalization itself but also during pre- and post-hospitalization delivery of care (e.g., outpatient, ancillary, physician visit). An episode payment system is therefore more patient-centered than a case-based payment system such as DRG. An episode payment system has not yet been implemented in Korea[44].

The Medicare inpatient care system in the United States is an example of a DRG-based payment system[13]. The Korean DRG (K-DRG) has been modified several times. The first pilot K-DRG project was implemented in 1997[45]. The official DRG payment system was selectively implemented in Korea in 2002. Seven principal diagnoses across four departments (Surgery; Ear, Nose, and Throat [ENT], Ophthalmology; and Obstetrics and Gynecology) were included in this initial DRG-based payment system. Compulsory participation of hospitals and clinics was effective as of July 2012. Compulsory participation was expanded to general and tertiary hospitals in July 2013. Thus, payments for all seven diagnoses covered under the DRG-based system have been paid by this system since July 2013, except those from long-term hospitals and public hospitals.

Many studies have examined the DRG-based payment system in Korea. According to a study by Kang et al. in 2009 and another by Choi et al. in 2012, LOS among patients covered by the DRG has decreased[46,47]. Other studies have reported that a decrease in LOS depends on the diagnosis. For example, Shin et al. reported that LOS decreased by 24.1% from 2.57 days to 1.95 days among patients who underwent lens surgery, but was not significantly decreased for any other diagnoses[48]. In 2006, Lee et al. reported that LOS decreased for several DRGs, except pediatric bilateral hernia procedures, laparoscopic hysterectomy, laparoscopic uterine and adnexa surgery, and Cesarean delivery[49]. According to the official presentation of HIRA in 2013, LOS among patients covered by the DRG-based payment system was decreased compared to patients with these diagnoses prior to the DRG-based payment system expansion. In particular, LOS for patients who received hemorrhoid procedures was dramatically decreased by 24.4%[50].

Other indices of patient care were also improved by the change to a DRG-based payment system. Kang et al. reported that the number of medical supplies provided by suppliers decreased by an average of 8.2% following DRG implementation, without a negative effect on patient care[51]. A decrease in medical supplies was observed among patients receiving lens surgery in particular. In addition, inpatient care fees (-40.8%), medication fees (-33.6%), injection fees (-30.0%), anesthesia fees (-17.4%), surgical material fees (-15.0%), and prescription days (-36.5%, from 3.23 days to 2.05 days) were decreased for unilateral lens surgery. Inpatient care fees (-27.0%), medication fees (-33.9%), injection fees (-21.6%), surgical material fees (-22.5%), and prescription fees (-19.4%, from 5.46 days to 4.40 days) were also decreased for bilateral lens surgery[52]. However, according to Choi et al., the readmission rate had increased[47].

Market competition has an effect on the impact of DRG implementation[15]. No side effects were observed for laparoscopic appendectomy[16]. According to Kim et al., there were no significant differences in perioperative outcomes and medical costs, except a shorter LOS, among patients who received an appendectomy. Shon et al. suggested that a non-significant reduction in LOS may have been related to the voluntary nature of participation in the DRG-based system[17,18]. Results from Song et al. suggest that Obstetrics and Gynecology clinics with an economic practice pattern under a fee-for-service system were more likely to participate in the DRG-based payment system than clinics that utilized a different system[19].

Japan experienced a dramatic increase in health expenditures over several decades under the FFS payment system. A pilot program of a DRG/PPS-like system was implemented in 1998 to control health expenditures[14]. Unlike in the United States, in Japan the reimbursement for hospitals and doctors is combined, and thus a DRG-based payment system is not suitable for Japan. In 2003, PPS with a DRG-rearranged grouping system called the diagnostic procedure combination/per-diem payment system (DPC/PDPS) was formally introduced in Japan. The major difference between the DPC and DRG is that the DPC/PDPS classifies inpatient activities first by diagnosis and then by procedure, whereas the DRG/PPS classification is a procedure-dominant system. In addition, DPC reimburses per diem and includes an FFS component for reimbursement of expensive procedures.

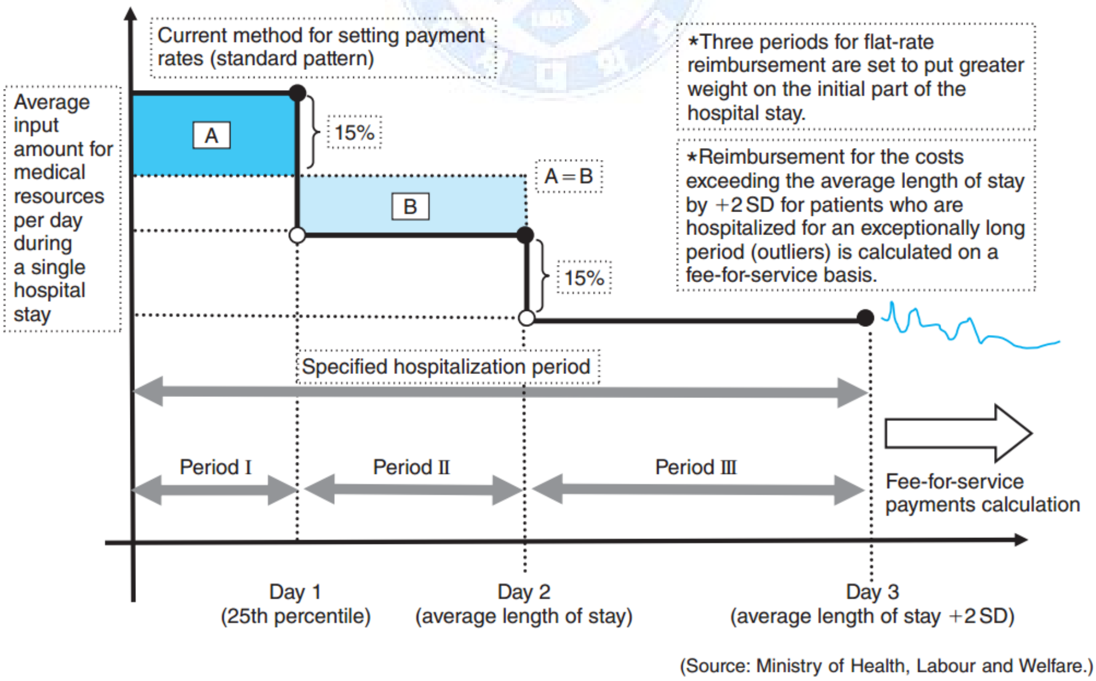

Figure 3. Method for setting per-diem payment rates in DPC payment rate (Ishii, 2012)

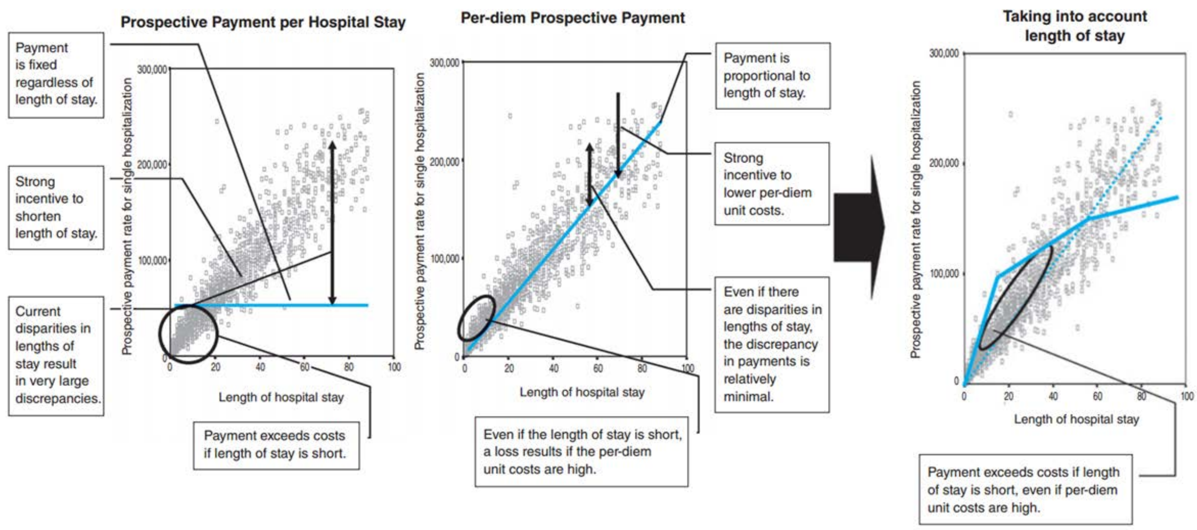

Figure 4. Comparison of prospective payment per hospital stay and per-diem prospective method (modified Ishii, 2012)

As shown in Figure 3, the per-diem fee schedule was associated with a short LOS[53]. This structure therefore provides incentives to decrease LOS. The per-diem rate varies by inpatient period. When the average LOS is dichotomized, LOS shorter than the average was associated with a 15% higher fee score, and LOS longer than the average was associated with a 15% lower fee score. Therefore, when a patient stays for an average LOS, the cumulative fee is the same as the average fee. When the LOS exceeds the average, the per-diem fee is discounted such that the average per-diem fee is decreased[7] (Figure 4).

The KDPC payment system, which was based on the Japanese DPC payment system, has been introduced by HIRA to expand the bundled payment system in Korea. The KDPC fee schedule, which is calculated as [basic case payment + (hospital days - average hospital days) × per-diem rate], reflects the difference between the average LOS and case LOS. This fee schedule includes a 20% fee for non-KDPC items; therefore, when the provider claims a fee for an FFS-scheduled item, this item is paid at 80%. Non-KDPC items include expensive procedures, materials, and pharmaceuticals that exceed 100,000 Korean Won (approximately 80 U.S. dollars), and are reimbursed by the FFS-based payment system (at 80%)[7]. According to Kang et al., the aim of this FFS schedule-based fee discount is to control the supplier’s behavior during the transition to a non-KDPC fee schedule.

The KDPC pilot project was implemented in one hospital in 2009 and was expanded to three large public hospitals in July 2011. Since July 2012, all public hospitals (39 medical institutions) have participated in the KDPC payment system for 550 principal DRGs. However, studies on the impact of the KDPC system are rare. According to a report by Kang et al., LOS associated with principal DRGs decreased by 0.13 days ($p = 0.48$) during the first pilot project and by 0.47 days ($p < 0.001$) for additional principal DRGs during the second pilot project. During the third pilot project, LOS for medical DRGs increased by 0.18 days ($p = 0.27$), LOS for surgical DRGs increased by 0.67 days ($p = 0.001$), and LOS for psychiatry DRGs decreased by 7.48 days ($p = 0.0001$)[54]. Similarly, Park et al. reported that LOS decreased by 1.9 days in the third pilot project, which was implemented in a public hospital. A difference analysis revealed a statistically significant decrease in LOS by 0.8 days in the third pilot project and by 0.9 days in the fourth pilot project[55,56]. In contrast, Kim et al. reported an increase in LOS in five principal DRGs and a decrease in LOS in one principal DRG among high frequency principal DRGs[21].

IV. Study Methods

1. Study design

In this study, hospitals that consistently participated in the DRG payment system from January 2007 to June 2012 and underwent a change in payment system to the KDPC payment system from July 2012 to June 2014 were defined as case hospitals. All case hospitals are public hospitals because the KDPC has been implemented in public hospitals only. Hospitals that consistently participated in the DRG payment system from January 2007 to June 2014 were defined as control hospitals. All control hospitals are private hospitals because these hospitals were not required to change to the KDPC system. Among the 39 public hospitals that implemented the KDPC payment system, two hospitals previously used an FFS payment system and were excluded from this study. Two additional hospitals were excluded from the study due to missing data. Therefore, 35 hospitals were included as case hospitals in our study. Among 1,996 medical institutes that were paid more than once by the DRG payment system for principal surgical DRGs, 326 institutes consistently participated in the DRG payment system. Clinics were excluded because no clinics were included as case hospitals. Therefore, 60 hospitals were included as control hospitals in this study.

The number of admissions to case hospitals was 39,364 and the number of admissions to control hospitals was 477,668. We conducted 1:2 sampling using the propensity score matching method for age, sex, Charlson comorbidity index (CCI), sub-DRG, and admission date (month). The area under the curve (AUC) value was 0.836. A total of 36,240 case admissions and 72,480 control admissions were included in the final analysis. Figure 5 shows the case and control groups during the study period and Figure 6 shows the selection of the study population.

The Institutional Review Board of Yonsei University Graduate School of Public Health approved the study (approval no. 2015-406).

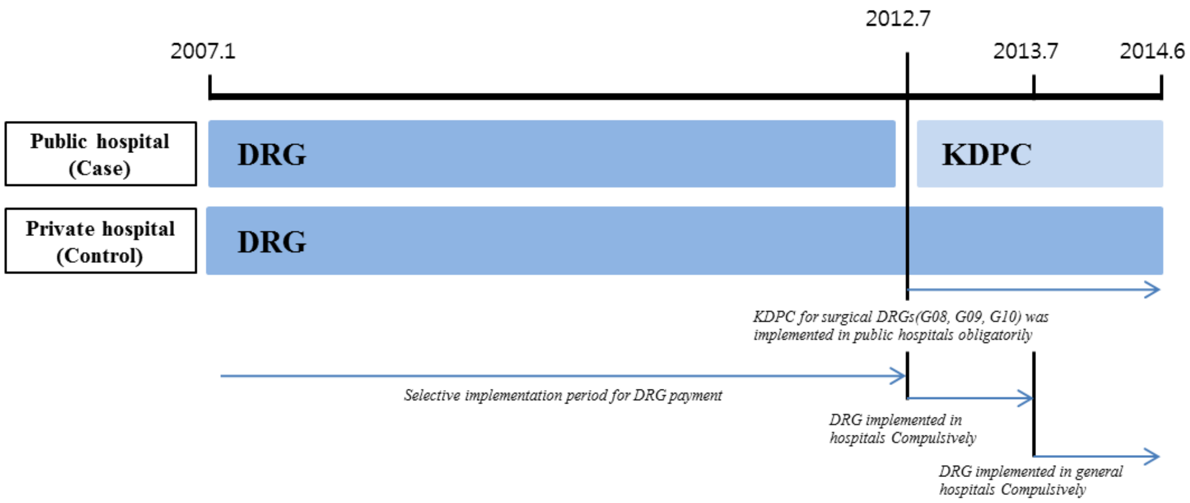

Figure 5. Study period for interrupted time series with case and control

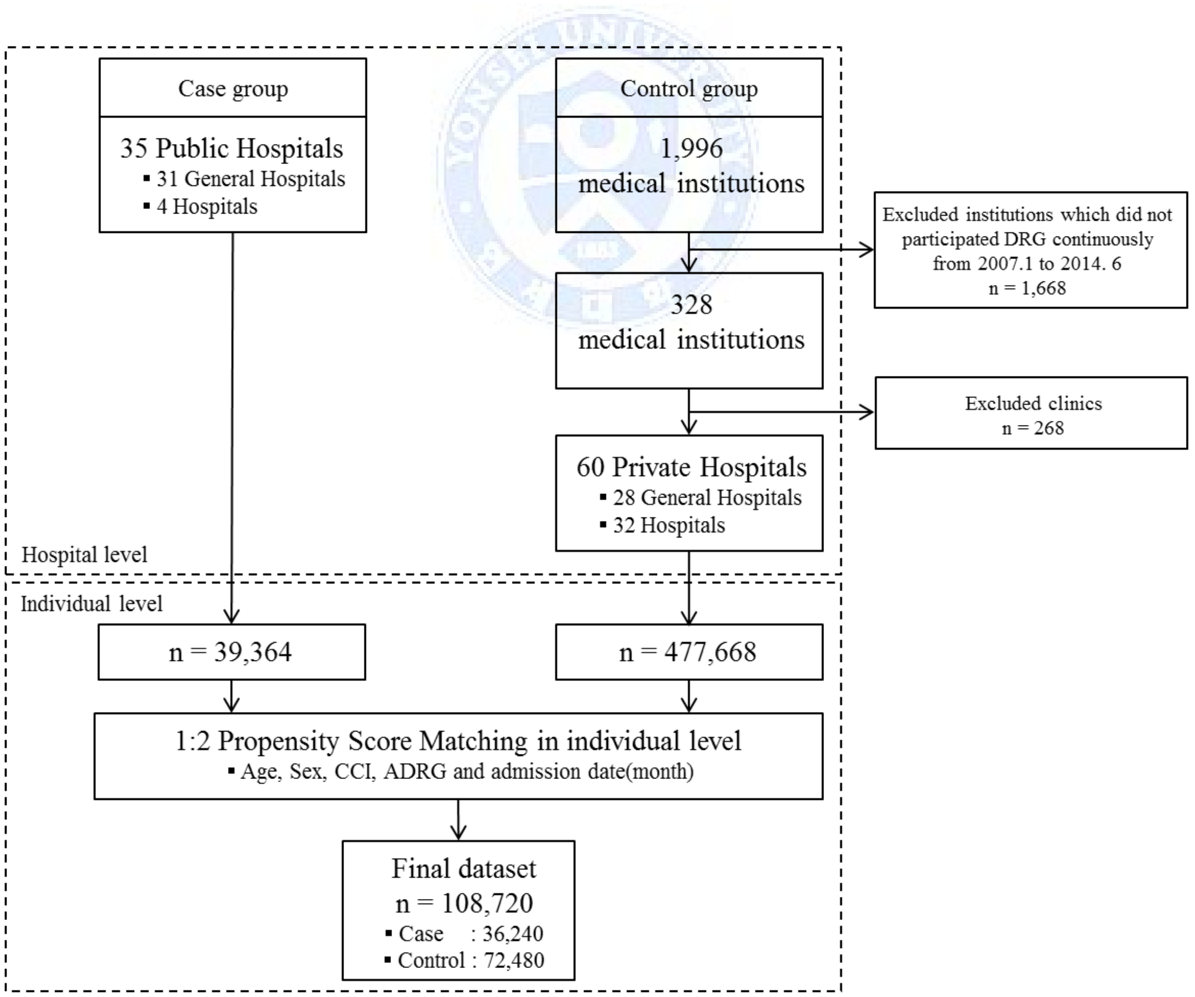

Figure 6. Selection of study population

2. Data and variables

This study used claim data provided by HIRA. Seven principal DRGs are included in the DRG payment system in Korea. Surgical principal DRGs include appendectomy (G08), hernia procedures (G09), and anal procedures (G10). Each principal DRG includes four sub-DRGs. Table 4 reports the sub-DRGs by principal DRGs.

Table 4. Sub-DRGs by principal DRGs in Surgery

DRG		Sub-DRG (Adjacent DRG, ADRG)	
G08	Appendectomy	G081	Appendectomy with complicated principal diagnosis
		G082	Appendectomy without complicated principal diagnosis
		G083	Laparoscopic appendectomy with complicated principal diagnosis
		G084	Laparoscopic appendectomy without complicated principal diagnosis
G09	Hernia procedures	G095	Inguinal & femoral hernia procedures without resection of intestine, unilateral, Laparoscopy
		G096	Inguinal & femoral hernia procedures without resection of intestine, unilateral
		G097	Inguinal & femoral hernia procedures without resection of intestine, bilateral, Laparoscopy
		G098	Inguinal & femoral hernia procedures without resection of intestine, bilateral
G10	Anal procedures	G102	Multiple anal procedures
		G104	Other anal procedures
		G105	Circular stapled hemorrhoidectomy
		G106	Major anal procedures

The dependent variable in our study is LOS of the admission case. LOS is a representative index that reflects the effectiveness of admission and is commonly used to evaluate the impact of a payment system change. Prior studies that have evaluated payment system change from a FFS-based payment system to a case-based payment system report a decrease in LOS under case-based systems. This result is expected due to the difference in cost-sharing between FFS and bundled payment systems. A case-based payment system, such as the DRG or KPDC, provides incentives to reduce LOS for-profit maximization. Therefore, LOS is considered a proper index to estimate differences between DRG and KDPC in this study. Theoretically, KDPC does not provide as much incentive to decrease LOS as DRG. Therefore, a change in LOS due a change from DRG to KDPC may reflect other effects in addition to economic incentives.

Age, sex, region (hospital location), sub-DRG, CCI, season, and year were included as individual-level covariates. Hospital type, ownership, teaching status, region, number of beds, number of doctors, and number of nurses were included as hospital-level covariates. Age, number of beds, number of doctors, and number of nurses were included as continuous variables. Sub-DRG included 12 subgroups (Table 4). CCI was calculated yearly based on Quan's methods[57]; 19 diseases were classified into scores of 1, 2, 3, or 6 (Table 5). CCI per subject was calculated from the sum of all scores. In this study, CCI was grouped as scores of 0, 1, 2, 3, and 4 or more. Four seasons were included to adjust for seasonal variations due to known seasonality in temperature and medical service utilization in Korea. Hospital type was classified as either general hospital or hospital. The bundled payment fee schedule varies between these two hospital types in Korea. Ownership was classified as public, corporate, or private. The KDPC was compulsory only in public hospitals; therefore, there are no private hospitals among the case hospitals and no public hospitals among the control hospitals. Teaching status (teaching or non-teaching) and region (urban or rural) were included as binary variables.

Table 5. Charlson comorbidity index scoring system

Score	Condition
1	Myocardial infarction Congestive heart failure Peripheral vascular disease Cerebrovascular disease Dementia Chronic pulmonary disease Connective tissue disease Ulcer disease Mild liver disease Diabetes
2	Hemiplegia Moderate-to-severe renal failure Diabetes w/ end organ damage Any malignancy Leukemia / lymphoma
3	Moderate or severe liver disease
6	Metastatic solid tumor AIDS/HIV

Source: Charlson et al.[57]

3. Statistical method

Segmented regression analysis of interrupted time series with control was carried out for analysis in this study, using the following equation (Equation 1):

$$
\begin{aligned}
Y_t = \beta_0 + \beta_1 time_t + \beta_2 KDPC\ implementation_t + \ \beta_3 time\ after\ KDPC\ implementation_t \\
+ \beta_4 Case + \beta_5 time_t \times \text{Case} + \beta_6 KDPC\ implementation_t \times \text{Case} \\
+ \ \beta_7 time\ after\ KDPC\ implementation_t \times Case + \beta_8 season_t + \mu_1 Z_1 + \cdots \\
+ \mu_p Z_p + \ e_t \cdots (1)
\end{aligned}
$$

Y_t: Average length of stay of month t

t: time period (month)

time: a continuous variable started in January 2007 by month

Case: a binary variable (0 Control hospitals; 1 Case hospitals)

KDPC implementation$_t$: a binary variable (0 before June 2012; 1 after July 2012)

time after KDPC implementation$_t$: a continuous variable started in July 2012

Season$_t$: seasonality (1 spring, 2 summer, 3 autumn, 4 winter)

$\mu_p Z_p$*:* independent variables (1⋯*p*)

$\boldsymbol{e}_t$ = Random variation in length of stay across time within hospital (within hospital variation)

In Equation 1, *β6* represents the level of change in the difference between case and control LOS at the time of KDPC implementation. *β7* represents the trend in the difference between case and control LOS after KDPC implementation. Equation 1 was implemented in PROC GENMOD (SAS version 9.4) as a generalized estimation equation (GEE) and mixed model with *link identity*, *distribution normal*, and *AR(1)*.

V. Results

Before propensity score matching, all variables were significantly different between cases and controls. Table 6 presents the general characteristics of the study population following the application of propensity score matching methods for age, sex, sub-DRG, and CCI. In addition, the time of the outcome was also included as a matching variable in order to implement time-series analysis for propensity score matching with 1:2 ratio samples. The AUC value of regression with these variables was 0.863. Tables S1 and S2 in the Appendix report general admission characteristics before and after propensity score matching by period.

Average LOS was significantly higher in cases compared with controls. There were no significant differences in average age between cases and controls (40.8 vs. 40.7 years, respectively). Over 60% of patients were male in both groups. Although we performed propensity score matching, the proportion of CCI classes remained significantly different between cases and controls; however, the proportion of each CCI level is more similar between groups than before matching was applied.

Table 6. General characteristics of admissions after Propensity Score Matching (n, %)

Variables	Case (n=36,240)		Control (n=72,480)		p-value
Length of Stay (mean, SD)	5.28	±2.36	4.80	±2.50	<0.001
Age (mean, SD)	40.8	±21.3	40.7	±21.1	0.155
<10	1,949	5.4	4,259	5.9	<0.001
10~19	5,928	16.4	11,613	16.0	
20~29	4,504	12.4	8,918	12.3	
30~39	5,079	14.0	9,949	13.7	
40~49	5,465	15.1	10,985	15.2	
50~59	5,143	14.2	10,577	14.6	
60~67	4,268	11.8	8,845	12.2	
>=70	3,904	10.8	7,334	10.1	
Sex					
Male	22,798	62.9	46,758	64.5	<0.001
Female	13,442	37.1	25,722	35.5	
Principal diagnosis					
Appendectomy	44,867	61.9	22,360	61.7	0.744
Hernia procedures	11,856	16.4	5,989	16.5	
Hemorrhoid procedures	15,757	21.7	7,891	21.8	
Charson comorbidity index					
0	17,416	48.1	34,693	47.9	0.007
1	5,987	16.5	11,994	16.6	
2	5,013	13.8	10,384	14.3	
3	4,228	11.7	8,639	11.9	
≥4	3,596	9.9	6,670	9.3	
Season					0.184
Spring	9,760	26.9	19,853	27.4	
Summer	9,617	26.5	18,851	26.0	
Autumn	7,707	21.3	15,533	21.4	
Winter	9,156	25.3	18,243	25.2	
Period					<0.001
2007.1~2008.6	7,435	20.5	15,506	21.4	
2008.7~2009.6	4,855	13.4	10,194	14.1	
2009.7~2010.6	5,007	13.8	9,867	13.6	
2010.7~2011.6	4,513	12.5	9,330	12.9	
2011.7~2012.6	4,935	13.6	9,494	13.1	
2012.7~2013.6	4,589	12.66	8,865	12.23	
2013.7~2014.6	4,906	13.54	9,224	12.73	
Total	36,240	33.3	72,480	66.7	

Table 7 presents the general characteristics of the study population at the hospital level. Case hospitals (n = 35) included 31 (88.6%) general hospitals and 4 (11.4%) hospitals. In contrast, control hospitals (n = 60) included 28 (46.7%) general hospitals and 32 (53.3%) hospitals. There was no significant difference in teaching status between case and control hospitals (p = 0.814). There were also no significant differences between cases and controls in the numbers of beds, doctors, or nurses (p = 0.4754, 0.5046, and 0.7156 respectively). A significant difference in hospital region was observed (71.4% vs. 36.7% rural for cases vs. controls, respectively; p = 0.0011).

Table 7. General characteristics of hospitals (n, %)

Variables	Case (n=35)		Control (n=60)		p-value
Hospital type					
General hospital	31	88.6	28	46.7	<0.0001
Hospital	4	11.4	32	53.3	
Hospital ownership					
Public	31	88.6	0	0	<0.0001
Corporation	4	11.4	28	46.7	
Private	0	0	32	53.3	
Teaching status					
Teaching	8	22.9	15	25.0	0.814
Non-teaching	27	77.1	45	75.0	
Region					
Urban	10	28.6	38	63.3	0.001
Rural	25	71.4	22	36.7	
Number of bed (means)	306.5	154.5	275.4	268.8	0.475
<300 bed	25	71.4	47	78.3	0.6780
300~499 bed	6	17.1	9	15.0	
500~700 bed	4	11.4	4	6.7	
Number of doctor (means)	31.2	31.0	38.1	67.7	0.5050
Number of nurse (means)	96.7	59.0	90.4	108.1	0.7160
Total	35	36.8	60	63.2	

Table 8 reports LOS for case and control hospitals stratified by several variables. Before implementation of the KDPC system, average LOS was 5.35 days (SD = 2.40) among cases and 4.85 days (SD = 2.46) among controls. After implementation of the KDPC system, average LOS was 5.06 days (SD = 2.23) among cases and 4.62 days (SD = 2.58) among controls. LOS increased with increasing age, and LOS was longer among female patients compared with male patients. Appendectomy had the longest LOS and hernia procedures had the second longest LOS. LOS was longer for higher CCI. Average LOS decreased over time from January 2007 to June 2014. LOS was longer at general hospitals compared with hospitals among cases. In contrast, among controls, LOS was longer at hospitals compared with general hospitals. LOS was longer in teaching hospitals compared with non-teaching hospitals. Average LOS was longer at rural hospitals compared with urban hospitals among controls; there was no significant difference in LOS between urban and rural hospitals among cases.

Table 8. Length of stay of hospitals by case and control (mean, SD)

Variables	Case (n=39,364)			Control (n=72,480)		
	Before Intervention, 2007.1~2012.6	After Intervention, 2012.7~2014.6	p-value	Before Intervention, 2007.1~2012.6	After Intervention, 2012.7~2014.6	p-value
Age						
<10	4.71 ±2.21	4.41 ±2.04	0.013	4.62 ±2.58	4.66 ±3.23	0.711
10~19	5.21 ±1.87	5.12 ±1.80	0.117	5.08 ±1.96	4.91 ±1.91	<0.0001
20~29	5.23 ±2.07	5.13 ±1.89	0.177	4.79 ±2.11	4.41 ±2.00	<0.0001
30~39	5.28 ±2.21	5.05 ±2.03	0.001	4.69 ±2.26	4.43 ±2.40	<0.0001
40~49	5.41 ±2.47	5.09 ±2.20	<0.0001	4.75 ±2.51	4.54 ±2.46	<0.0001
50~59	5.57 ±2.75	5.09 ±2.38	<0.0001	4.83 ±2.62	4.53 ±2.60	<0.0001
60~67	5.47 ±2.58	5.01 ±2.43	<0.0001	4.84 ±2.83	4.70 ±3.00	0.044
>=70	5.69 ±2.98	5.15 ±2.80	<0.0001	5.16 ±3.02	4.77 ±3.13	<0.0001
Sex						
Male	5.23 ±2.38	4.90 ±2.26	<0.0001	4.67 ±2.45	4.41 ±2.56	<0.0001
Female	5.55 ±2.44	5.35 ±2.16	<0.0001	5.18 ±2.46	5.02 ±2.58	<0.0001
Principal diagnosis						
Appendectomy	5.75 ±2.27	5.61 ±2.12	<0.0001	5.66 ±2.36	5.58 ±2.53	0.002
Hernia procedures	4.93 ±2.23	4.38 ±2.22	<0.0001	3.91 ±2.22	3.50 ±2.28	<0.0001
Hemorrhoid procedures	4.53 ±2.61	4.07 ±2.07	<0.0001	3.16 ±1.70	3.02 ±1.61	<0.0001
Charson comorbidity index						
0	5.17 ±2.07	5.03 ±1.93	<0.0001	4.84 ±2.18	4.61 ±2.26	<0.0001
1	5.40 ±2.44	5.06 ±2.19	<0.0001	4.74 ±2.49	4.49 ±2.41	<0.0001
2	5.56 ±2.72	5.09 ±2.37	<0.0001	4.82 ±2.64	4.57 ±2.68	<0.0001
3	5.49 ±2.57	4.98 ±2.37	<0.0001	4.86 ±2.80	4.68 ±2.96	0.011
≥4	5.74 ±3.11	5.23 ±2.90	<0.0001	5.22 ±3.11	4.83 ±3.19	<0.0001
Season						
Spring	5.34 ±2.41	5.10 ±2.24	<0.0001	4.85 ±2.44	4.57 ±2.52	<0.0001
Summer	5.35 ±2.37	5.01 ±2.27	<0.0001	4.90 ±2.45	4.68 ±2.64	<0.0001
Autumn	5.37 ±2.37	5.14 ±2.29	<0.0001	4.90 ±2.49	4.67 ±2.58	<0.0001
Winter	5.35 ±2.46	5.02 ±2.13	<0.0001	4.77 ±2.48	4.57 ±2.58	<0.0001
Period						
2007.1~2008.6	5.64 ±2.36		<0.0001	5.00 ±2.51		<0.0001
2008.7~2009.6	5.45 ±2.31			4.88 ±2.37		
2009.7~2010.6	5.28 ±2.43			4.83 ±2.45		
2010.7~2011.6	5.14 ±2.43			4.79 ±2.51		
2011.7~2012.6	5.09 ±2.46			4.68 ±2.45		
2012.7~2013.6		4.98 ±2.16			4.64 ±2.57	
2013.7~2014.6		5.14 ±2.30			4.60 ±2.59	
Hospital type						
General hospital	5.33 ±2.38	5.04 ±2.23	<0.0001	5.47 ±2.37	5.42 ±2.51	0.092
Hospital	5.79 ±2.80	5.47 ±2.34	0.031	4.26 ±2.41	3.87 ±2.41	<0.0001
Hospital ownership						
Public	5.40 ±2.38	5.12 ±2.21	<0.0001	- -	- -	
Corporation	5.03 ±2.50	4.70 ±2.38	<0.0001	5.51 ±2.48	5.44 ±2.58	0.033
Private	- -	- -		4.37 ±2.34	3.99 ±2.40	<0.0001
Teaching status						
Teaching	5.72 ±2.39	5.33 ±2.28	<0.0001	5.35 ±2.29	5.45 ±2.44	0.007
Non-teaching	5.19 ±2.39	4.95 ±2.20	<0.0001	4.67 ±2.50	4.32 ±2.56	<0.0001
Region						
Urban	5.48 ±2.57	5.03 ±2.43	<0.0001	4.61 ±2.46	4.37 ±2.57	<0.0001
Rural	5.30 ±2.33	5.08 ±2.14	<0.0001	5.56 ±2.35	5.39 ±2.47	<0.0001
Number of bed (means)						
<300 bed	5.16 ±2.33	4.92 ±2.06	<0.0001	4.53 ±2.47	4.13 ±2.49	<0.0001
300~499 bed	5.61 ±2.34	5.76 ±2.37	0.022	5.54 ±2.00	5.29 ±1.86	<0.0001
500~700 bed	5.72 ±2.52	5.22 ±2.38	<0.0001	5.16 ±2.36	5.24 ±2.72	0.347
Total	5.35 ±2.40	5.06 ±2.23	<0.0001	4.85 ±2.46	4.62 ±2.58	<0.0001

Table 9 reports average LOS of cases and controls stratified by time period. Among cases, average LOS was observed to decrease prior to KDPC implementation and increase after KDPC implementation. In contrast, among controls, average LOS consistently decreased both before and after the time at which the KDPC system was implemented. Total p-for-trend was significant for both cases and controls. When stratified by DRGs, p-for-trend remained significant for cases only.

Table.9 Average LOS of case and control by time period (days)

		2007.1~2008.6		2008.7~2009.6		2009.7~2010.6		2010.7~2011.6		2011.7~2012.6		*p for trend*	2012.7~2013.6		2013.7~2014.6		*p for trend**
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Total	Case	5.64	±2.36	5.45	±2.31	5.28	±2.43	5.14	±2.43	5.09	±2.46	<0.0001	4.98	±2.16	5.14	±2.30	<0.0001
	Control	5.00	±2.51	4.88	±2.37	4.83	±2.45	4.79	±2.51	4.68	±2.45	0.0151	4.64	±2.57	4.60	±2.59	0.0275
Appendectomy	Case	5.96	±2.27	5.78	±2.19	5.71	±2.36	5.60	±2.25	5.59	±2.27	0.0062	5.56	±2.07	5.67	±2.16	0.0183
	Control	5.78	±2.39	5.65	±2.22	5.63	±2.37	5.66	±2.42	5.52	±2.38	0.0869	5.60	±2.52	5.57	±2.53	0.1961
Hernia procedures	Case	5.43	±2.34	5.16	±2.19	4.87	±2.05	4.66	±2.38	4.37	±1.95	<0.0001	4.20	±1.96	4.56	±2.42	0.0003
	Control	4.01	±2.24	3.90	±2.17	4.02	±2.20	3.79	±2.27	3.83	±2.19	0.3046	3.49	±2.19	3.52	±2.36	0.2593
Hemorrhoid procedures	Case	4.91	±2.44	4.66	±2.53	4.32	±2.52	4.30	±2.63	4.23	±2.95	0.0261	4.05	±2.02	4.10	±2.11	0.0001
	Control	3.27	±1.82	3.12	±1.65	3.12	±1.62	3.12	±1.62	3.10	±1.71	0.2028	3.08	±1.66	2.96	±1.55	0.0774

*for total duration (2007.1~2014.6)

1. Results of segmented regression analysis of interrupted time series with control

Table 10 reports the results of the segmented regression analysis with control for case and control LOS. The estimate for *Baseline trend in difference between cases and controls*, -.0007 (p-value 0.0412), reflects a trend in the difference in LOS between cases and controls prior to KDPC implementation. The estimate for *Level change in difference between cases and control*s reflects a difference in the change of LOS between cases and controls at the time of KDPC implementation. As reported in Table 10, the difference in LOS between cases and controls was as much as 0.117 days at the time of KDPC implementation, but was not statistically significant (p = 0.4366). The estimate for *Trend change in difference between cases and control*s reflects the change in trend difference in LOS between cases and controls after implementation. Thus, an estimate of 0.025 indicates that the trend difference in LOS between cases and controls was an increase in 0.025 days (p = 0.0055) compared with baseline.

We also performed a comparative interrupted time series analysis (CITS, trend-adjusted difference-in-difference analysis) using Equation S1. The results of this analysis are reported in Table S8. Furthermore, using Equation S3 we predicted changes in LOS 12, 24, 36’ and 48 months after KDPC implementation. These results are reported in Table S13 and Figure S3.

Table 10. Results of the segmented regression analysis with control for LOS

Parameter		Estimate	SE	95% Confidence Limits		p-value
Intercept β		3.164	0.367	2.445	3.883	<.0001
Baseline trend		-0.002	0.004	-0.010	0.005	0.5827
Level change		-0.012	0.061	-0.132	0.108	0.8450
Trend change		-0.004	0.006	-0.016	0.009	0.5877
Difference between case and control		0.186	0.268	-0.339	0.711	0.4872
Baseline trend of difference between case and control		**-0.007**	0.003	-0.014	0.000	0.0412
Level change of difference between case and control		-0.117	0.150	-0.412	0.178	0.4366
Trend change of difference between case and control		**0.025**	0.009	0.008	0.043	0.0055
Age		0.016	0.002	0.013	0.018	<.0001
Sex	Male	-0.099	0.019	-0.136	-0.063	<.0001
	Female	ref.				
Sub DRG	G081	3.922	0.223	3.485	4.360	<.0001
	G082	1.154	0.144	0.872	1.435	<.0001
	G083	2.896	0.390	2.132	3.661	<.0001
	G084	0.906	0.154	0.604	1.207	<.0001
	G095	-0.463	0.307	-1.064	0.138	0.1308
	G096	-0.077	0.200	-0.469	0.316	0.7028
	G097	-0.606	0.357	-1.304	0.093	0.0895
	G098	0.216	0.331	-0.432	0.865	0.5129
	G102	0.146	0.082	-0.016	0.307	0.0766
	G104	-1.058	0.171	-1.393	-0.722	<.0001
	G105	-0.347	0.240	-0.818	0.123	0.1477
	G106	ref.				
Charlson comorbidity index	0	-0.163	0.095	-0.350	0.023	0.0858
	1	-0.247	0.087	-0.417	-0.076	0.0047
	2	-0.234	0.076	-0.384	-0.085	0.0021
	3	-0.247	0.050	-0.346	-0.148	<.0001
	≥4	ref.				
Hospital type	General Hospital	0.118	0.291	-0.452	0.688	0.6846
	Hospital	ref.				
Hospital ownership	Public	0.454	0.358	-0.247	1.156	0.2044
	Corporation	0.365	0.277	-0.179	0.909	0.1885
	Private	ref.				
Teaching status	Teaching	0.584	0.190	0.212	0.955	0.0021
	Non-teaching	ref.				
Region	Urban	-0.034	0.224	-0.472	0.405	0.8808
	Rural	ref.				
SEASON	Spring	-0.049	0.017	-0.083	-0.015	0.0045
	Summer	-0.044	0.021	-0.086	-0.003	0.0378
	Autumn	-0.038	0.025	-0.086	0.011	0.1275
	Winter	ref.				
Year	2007	0.143	0.261	-0.368	0.654	0.5832
	2008	0.118	0.217	-0.307	0.543	0.5849
	2009	0.059	0.194	-0.321	0.438	0.7612
	2010	0.115	0.157	-0.194	0.423	0.4654
	2011	0.059	0.131	-0.197	0.315	0.6509
	2012	-0.020	0.118	-0.252	0.212	0.8634
	2013	0.067	0.064	-0.059	0.193	0.2962
	2014	ref.				
Number of Bed		0.003	0.001	0.002	0.004	<.0001
Number of doctor		-0.005	0.001	-0.007	-0.003	<.0001
Number of Nurse		-0.005	0.002	-0.009	-0.002	0.0005

Table 11 reports the results of the segmented regression analysis with control for LOS stratified by DRG. The estimate for *Trend change in difference between cases and controls* is 0.021 (p = 0.0496) for appendectomy and 0.040 (p = 0.0058) for hernia procedures. In addition, the estimate for *Baseline trend in difference between cases and controls* is 0.015 (p = 0.0033). No significant estimates were found for hemorrhoid procedures. Table S3-S5 reports the full results of segmented regression analysis with control for LOS for three surgical DRGs.

Table 11. Results of the segmented regression analysis with control for LOS by DRG

Parameter	Estimate	SE	95% Confidence Limits		p-value
Appendectomy					
Intercept β	5.551	0.535	4.503	6.598	<.0001
Baseline trend	-0.002	0.005	-0.012	0.008	0.6720
Level change	0.037	0.074	-0.109	0.182	0.6222
Trend change	-0.004	0.009	-0.021	0.013	0.6151
Difference between case and control	0.042	0.235	-0.419	0.502	0.8598
Baseline trend of difference between case and control	-0.005	0.004	-0.012	0.003	0.2680
Level change of difference between case and control	-0.161	0.176	-0.506	0.184	0.3595
Trend change of difference between case and control	**0.021**	0.011	0.000	0.041	**0.0496**
Hernia procedures					
Intercept β	0.762	0.743	-0.695	2.219	0.3051
Baseline trend	**-0.017**	0.008	-0.033	-0.001	0.0376
Level change	-0.129	0.149	-0.421	0.163	0.3862
Trend change	0.012	0.013	-0.013	0.037	0.3480
Difference between case and control	-0.131	0.407	-0.928	0.666	0.7472
Baseline trend of difference between case and control	**-0.015**	0.005	-0.025	-0.005	0.0033
Level change of difference between case and control	0.091	0.218	-0.337	0.519	0.6772
Trend change of difference between case and control	**0.040**	0.014	0.011	0.068	0.0058
Hemorrhoid procedures					
Intercept β	2.734	0.596	1.567	3.902	<.0001
Baseline trend	0.006	0.007	-0.007	0.019	0.3373
Level change	-0.011	0.091	-0.190	0.168	0.9071
Trend change	-0.012	0.009	-0.030	0.006	0.1837
Difference between case and control	0.646	0.369	-0.077	1.369	0.0800
Baseline trend of difference between case and control	-0.010	0.006	-0.022	0.002	0.1027
Level change of difference between case and control	-0.196	0.285	-0.755	0.363	0.4914
Trend change of difference between case and control	0.022	0.017	-0.012	0.055	0.2072

Adjusted age, sex, CCI, hospital type, hospital ownership, teaching status season, year, number of bed, number of doctor and number of nurse

The time-series graph in Figure 7 reports average LOS for total admissions stratified by month. Red dots represent monthly average LOS for cases and blue dots represent average LOS for controls. The red dotted line represents the average standard LOS (4.89 days) for KDPC admissions, and the blue dotted line represents the average standard LOS (5.20 days) for DRG admissions. LOS consistently decreased among controls, whereas LOS decreased among cases and then increased following KDPC implementation.

Time-series graphs for three surgical DRGs are shown in Figures 7-10. For appendectomy, LOS trend lines overlapped between cases and controls (Figure 8). However, after adjusting for confounding variables, an increasing trend in LOS was observed after KDPC implementation among cases. An increasing trend in LOS among cases after KDPC implementation is more obvious for hernia procedures (Figure 9). The trend change is relatively small in hemorrhoid procedures compared with other DRGs (Figure 10).

We also performed the analysis using a negative binomial distribution, as well as a Poisson distribution with identity link. These results are reported in Table S14.

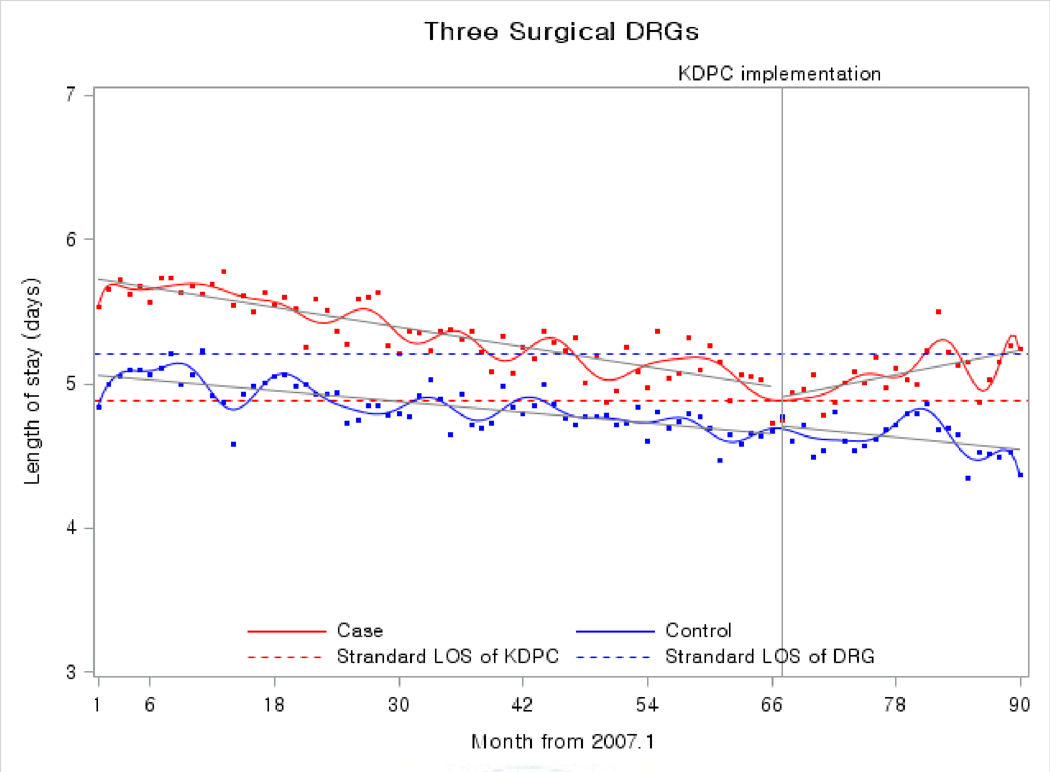

Figure 7. Time series, surgical DRSs

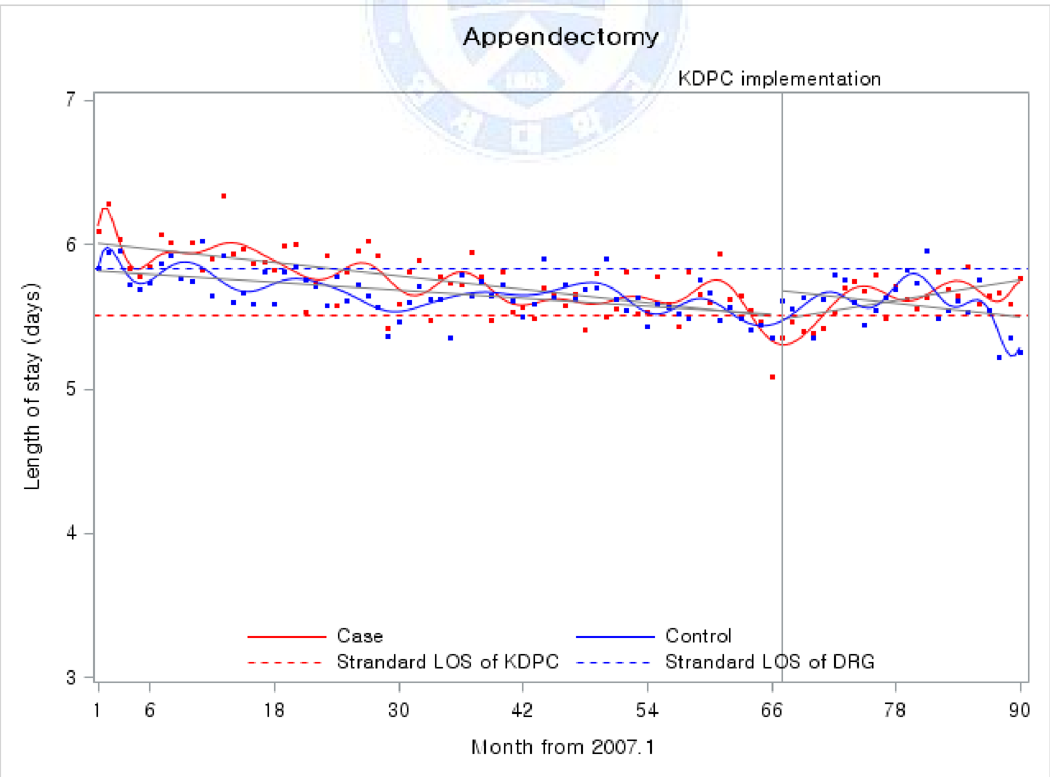

Figure 8. Time series, Appendectomy

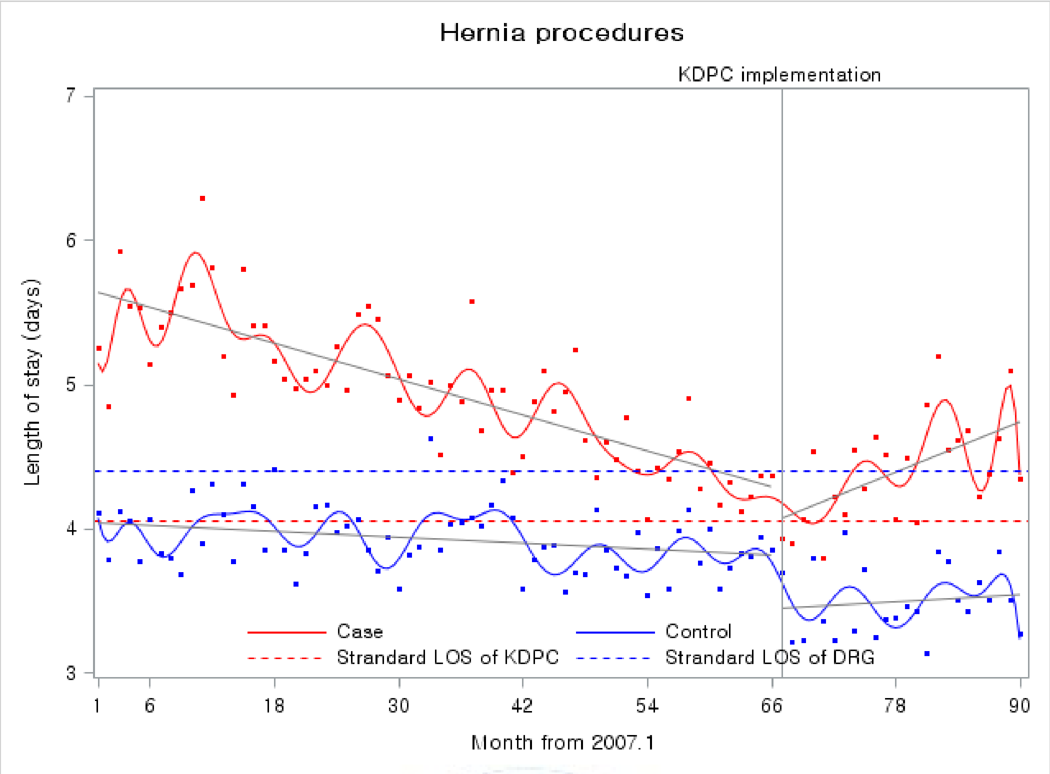

Figure 9. Time series, Hernia procedures

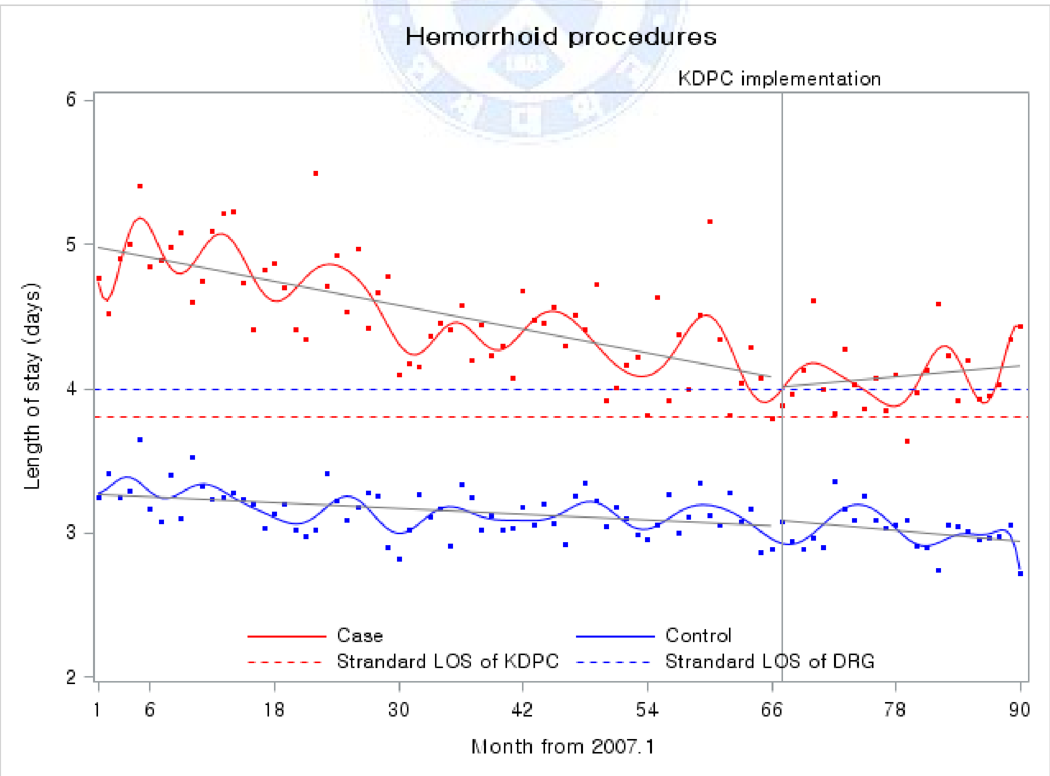

Figure 10. Time series, Hemorrhoid procedures

2. Results of subgroup analyses

We performed subgroup analyses to determine which subgroup was more influenced by KDPC implementation. Subgroup analyses were performed for total, appendectomy, hernia, and hemorrhoid procedures. We used Equation 1 to evaluate statistically significant differences among subgroups. Results of subgroup analyses for CCI and hospital type are reported in Tables 12 and 13 and Figures 11 and 12, respectively.

Table 12 reports the results of the segmented regression analysis with control for LOS stratified by CCI subgroup. Among total admissions, those with a higher CCI exhibited a higher increasing trend change in LOS (CCI 0, 1: 0.022, $p = 0.0142$; CCI 2, 3: 0.026, $p = 0.0288$; CCI $\geq$ 4: 0.055, $p = 0.0003$). Among appendectomy admissions, only the CCI $\geq$ 4 subgroup exhibited a statistically significant estimate for *Trend change in difference between cases and controls*" (0.077, $p = 0.0044$). Among hernia procedure admissions, all CCI subgroups exhibited a statistically significant increasing trend change (CCI 0, 1: 0.033, $p = 0.0361$; CCI 2, 3: 0.049, $p = 0.0045$; CCI $\geq$ 4: 0.043, $p = 0.0379$).

Figure 11 shows the estimate values of level and trend changes in the difference between cases and controls from Table 12 as a bar graph.

Table 12. Results of the segmented regression analysis with control for LOS by CCI subgroup

		Level change of difference between Public and private			Trend change of difference between Public and private		
		Estimate	SE	p-value	Estimate	SE	p-value
Total	0, 1	-0.163	0.150	0.2794	**0.022**	0.009	0.0142
	2, 3	-0.148	0.204	0.4690	**0.026**	0.012	0.0288
	≥4	0.161	0.221	0.4664	**0.055**	0.015	0.0003
Appendectomy	0, 1	-0.181	0.169	0.2855	0.019	0.010	0.0608
	2, 3	-0.068	0.254	0.7891	0.018	0.016	0.2422
	≥4	-0.270	0.563	0.6308	**0.077**	0.027	0.0044
Hernia procedures	0, 1	-0.038	0.263	0.8844	**0.033**	0.016	0.0361
	2, 3	-0.021	0.312	0.9465	**0.049**	0.017	0.0045
	≥4	0.243	0.286	0.3965	**0.043**	0.021	0.0379
Hemorrhoid procedures	0, 1	-0.179	0.282	0.5254	0.021	0.016	0.1927
	2, 3	-0.329	0.357	0.3556	0.012	0.021	0.5545
	≥4	-0.289	0.436	0.5072	0.066	0.037	0.0721

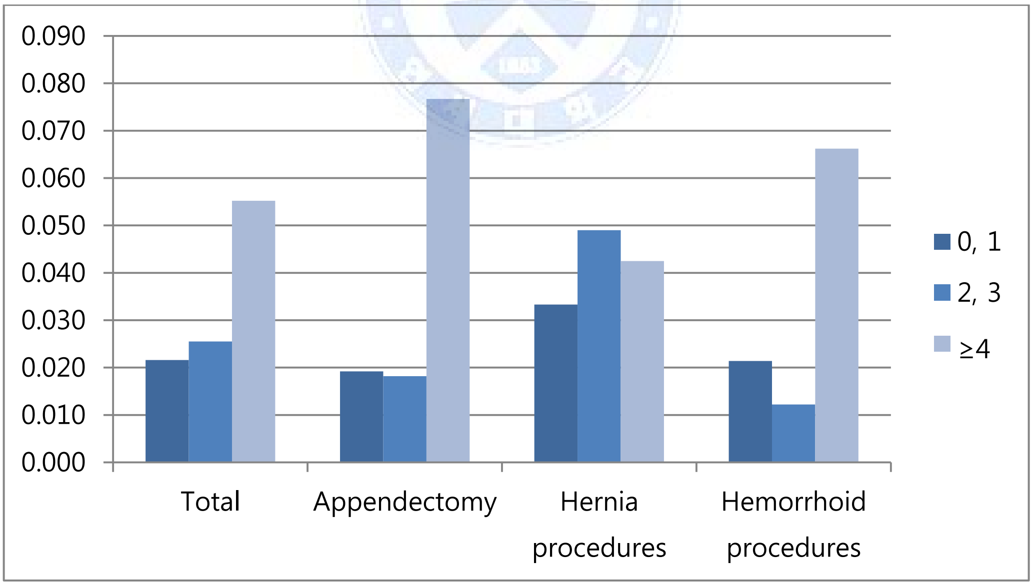

Figure 11. Results of the segmented regression analysis with control for LOS by CCI subgroup

Table 13 reports the results of the segmented regression analysis with control for LOS by hospital type subgroup. Among total admissions, the estimate for *Trend change in difference between cases and controls* was significant for the general hospital subgroup (0.030, p = 0.0048). Similarly, for appendectomy admissions, the estimate for *Trend change in difference between cases and control*s was statistically significant for the general hospital subgroup only (0.024, p = 0.0447). In contrast, for hernia procedures, the trend change estimates for both the general hospital and hospital subgroups were statistically significant (general hospital: 0.043, p =0.0091; hospital: -0.125, p = < 0.001). Significant level changes in difference between cases and controls were also observed for hernia procedures among the hospital subtype (2.589, p = 0.0285) and for hemorrhoid procedures among the general hospital subtype (-1.086, p = 0.0006).

Figure 12 reports the estimate values for level and trend changes in the difference between cases and controls from Table 13 as a bar graph.

Table 13. Results of the segmented regression analysis with control for LOS by hospital type subgroup

		Level change of difference Public and private			Trend change of difference Public and private		
		Estimate	SE	p-value	Estimate	SE	p-value
Total	General hospital	-0.097	0.163	0.5512	**0.030**	0.011	0.0048
	Hospital	-0.398	0.408	0.3291	0.010	0.023	0.6513
Appendectomy	General hospital	-0.094	0.183	0.6082	**0.024**	0.012	0.0447
	Hospital	-0.668	0.488	0.1709	0.024	0.019	0.1982
Hernia procedures	General hospital	-0.089	0.225	0.6938	**0.043**	0.017	0.0091
	Hospital	**2.589**	1.182	0.0285	**-0.125**	0.029	<.0001
Hemorrhoid procedures	General hospital	**-1.086**	0.318	0.0006	-0.004	0.024	0.8645
	Hospital	-0.307	0.352	0.3830	0.030	0.020	0.1277

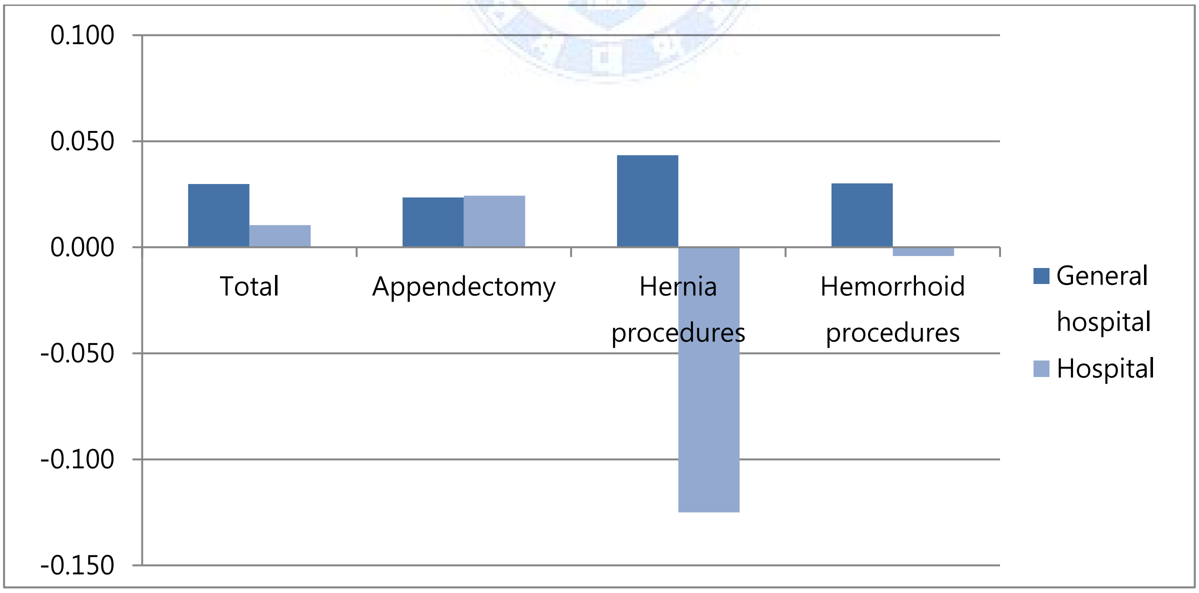

Figure 12. Results of the segmented regression analysis with control for LOS by hospital type subgroup

We also conducted segmented regression analysis with control for LOS by region and teaching status. These results are reported in the Appendix in Tables S6 and S7 and Figures S1 and S2. In addition, we performed comparative interrupted time-series analysis (i.e., trend-adjusted difference-in-difference [DID] analysis) and trend-adjusted triple difference-in-difference analysis using Equations S1 and S2, respectively. The results of these analyses are reported in Tables S9-S12. Furthermore, using Equation S3, we predicted an LOS change effect at 12, 24, 36, and 48 months after KDPC implementation by subgroups. These results are reported in Tables S14-S17 and Figures S4-S7.

VI. Discussion

1. Discussion of study methods

There are obvious differences between case and control hospitals in this study. Hospitals in the case hospital group are all public hospitals that were forced into participating in the DRG pilot project for political reasons, whereas hospitals in the control hospital group are all private hospitals. Differences between public and private hospital are well known[58]. In addition, the results of this study suggest a significant difference in LOS between these two hospital groups. Average LOS was 5.28 days (± 2.36 days) among case hospitals and 4.80 days (± 2.50 days) among control hospitals, which indicates that a direct comparison between groups is meaningless. Therefore, we conducted a time series analysis before and after implementation With control group.

Previous studies that analyzed the impact of policy changes mainly used the DID [59-61] and time-series[62-66] methods. In this study, the effect of the new payment system was identified by segmented regression analysis of an interrupted time series with control. Interrupted time-series analysis is a popular method for policy evaluation[67-71]. Most studies using segmented analysis have analyzed time-aggregated data without considering individual-level effects. In contrast, a study by Sen et al.[72] used segmented regression analysis with data aggregated into "person-months." The present study implemented segmented regression analysis based on the method by Sen et al. to overcome limitations in the unadjusted case-mix that is present in most studies. In addition, we used a GEE model, which provides a flexible approach to analyze correlated data from the same individuals over time[73,74]. The main limitation of a mixed-model approach is the assumption of residual normality[75,76]. Recent studies have used a regression method to adjust individual variables[77,78]. However, the GEE is comparable for a continuous dependent variable[79]. Thus, the study results were interpreted based on the GEE.

We analyzed the change in average LOS over the 2 years after KDPC implementation (Table S8). In the time-series graph in Figure 7, a decreasing trend is observed in both the cases and controls until the time of KDPC implementation. After this point, an increase in average LOS is observed in the cases (V-shaped time-series graph, Figure 7). Therefore, it is difficult to determine the effect on LOS change from average LOS over a particular period.

2. Discussion of results

The results of this study suggest that the payment system change from DRG to KDPC increased LOS. However, this effect was not consistent across three surgical DRGs and was significant for appendectomy and hernia procedures only. Compared with the other two surgical DRGs, hemorrhoid procedures are relatively non-invasive, LOS is usually short, emergency procedures or complex cases are relatively rare, and the level of surgical difficulty is low (based on the relative value resource based scale, RVRBS). Although we cannot conclude that these characteristics contributed to the result observed in the current study, we cannot conceive of other reasons for differences. If the difference is associated with DRG invasiveness, then the severity of admission may also have a similar association with the impact.

The results of stratified analysis by severity (i.e., CCI) are consistent with this expectation. The impact of the payment system change on the trend change in LOS is twice as high in the highest severity group (CCI ≥ 4: 0.055) compared with the lowest severity group (CCI 0, 1: 0.022). This result is observed for each DRG subtype in the stratified analysis by severity degree. This association is also observed for the hospital type subgroup analysis. General hospitals are larger than hospitals. In addition, more patient cases are generally admitted to general hospitals. Therefore, our hypothesis that the payment system change would have more of an impact on high severity cases (or complex procedures) is appropriate.

It is unclear, however, why LOS among more severe cases is more susceptible to payment system change. The transition from a DRG- to KDPC-based payment system reduces the incentive to decrease LOS. According to Ishii[53], the fee schedule structure of DRG provides more incentives for decreasing LOS than the Japanese DPC. Given that the fee schedule structure of KDPC is very similar to the original Japanese DPC, we can infer that incentives to decrease LOS are attenuated in the KDPC-based system.

Despite the attenuated incentives for decreasing LOS in the KDPC compared with the DRG, the structure of the KDPC fee schedule is per diem, with profit maximized for shorter LOS. Therefore, an increase in LOS due to a change in the payment system means that the payment system change also is associated with profit minimization. There exists, therefore, a tradeoff between decreasing LOS and profit maximization between the DRG- and KDPC-based payment systems. The impact of this tradeoff is the greatest for high severity admission cases. Although it is difficult to define what an appropriate LOS is, the fact that LOS increased only in high severity cases suggests that the DRG system provides excessive incentives to reduce LOS for high severity cases.

This increase in LOS should be interpreted differently than the LOS decrease that was observed following the payment system change from FFS to DRG. Under FFS, long LOS is associated with profit maximization, whereas long LOS is associated with a decrease in average profits under KDCP. Therefore, increasing LOS in the present study suggests that the DRG-based system promotes excessive decreases in LOS in certain situations in Korea.

There are several reasons for the observation of LOS decrease under DRG but not KDPC. First, the financial incentives for LOS decrease are higher for DRG than KDPC. In Figure 7, the blue dotted line, which represents the standard average LOS for DRG, was located above the blue dot that represents the real average LOS for that month. This finding indicates that money was saved under the DRG-based system, because the DRG fee schedule is designed to compensate costs during standard LOS. Despite these savings, however, average LOS continuously decreases under the DRG-based system. In contrast, the red dotted line, which represents the average standard LOS for three surgical DRGs under the KDCP-based system, is located mainly below the red dots during the KDPC period (2012.7-2014. 6). KDPC admissions with LOS longer than the standard LOS incur a financial penalty due to the decreasing per-diem fee schedule. Despite this penalty, we observed that average LOS increases under the KDPC-based system. If LOS increase is due to financial incentives, then LOS should not increase over the standard LOS. Therefore, differences in financial incentives alone cannot explain the results of our study.

A second possible explanation is the contribution of “checks and balances”. “Checks and balances” refers to the balance between the medical decisions of the physicians and the pressure of the hospital manager. Unlike in the U.S., physicians’ fees and hospital fees are not separate in Korea. In addition, the medical fees of the NHI are relatively low compared with the U.S. Therefore, the physician’s decision has less of an impact than the manager’s decision. Thus, in contrast to FFS or a per-diem fee schedule, which give more power to the physician’s professional decision, checks and balances are more difficult to achieve under a DRG-based system[80,81]. Checks and balances may be easier to achieve under KDPC due to structural differences in the payment system. However, Kwon insists that a checks and balances structure is meaningless in Korea, because most physicians are employed by the hospital and there are few checks and balances between the hospital and the physician in terms of quality, which is in contrast to the attending system in the U.S.[8]. Therefore, to identify the existence and action of checks and balances in Korea, other indexes about health care outcomes or processes, such as spending resources and mortality, should be investigated in future studies.

We performed CITS analysis and trend-adjusted triple difference-in-difference analysis. CITS compares the average over a particular period; therefore, differences may be masked when the trend change is slight and comparing period is not long enough. However, the results from this CITS analysis were not significantly different from the results of segmented regression analysis (Tables S8-S12).

3. Discussion about payment system and LOS

This study aimed to compare two bundled payment systems to provide evidence for the development of a proper reimbursement system in Korea. The findings from this study suggest that the DRG-based payment system provides too much incentive to decrease LOS for high severity cases. Average LOS in Korea is the second longest among the Organisation for Economic Co-operation and Development (OECD) countries after Japan. Short LOS is therefore a high priority public health problem. However, it is doubtful that a change in payment system that only reduces the LOS, and does not have any other benefit, is an appropriate choice.

The impact of payment system on medical services and supplies is well known[1-3]. Figure 1 shows that larger payment units are associated with more provider financial risk as well as risk of patient undertreatment. However, increase in patient undertreatment risk is not directly associated with LOS decrease. Previous studies are counterexamples[36-38]. In those studies, the payment system changed to DRG from a budgeting system, which may explain the cost component shown in Figure 2. There are Incentives under FFS when costs and the number of processes (numerator of FFS component) are reduced and the number of services (payment unit) are expanded. Because LOS is one of the "number of services", therefore, reducing LOS has not incentive under FFS. Under case payment, there are incentives when cost, number of processes, and number of services (numerator of case payment) are reduced and the number of case (payment unit) are expanded. So, under case payment, reducing LOS has incentives. Similarly, under episode-of-care payment, there are incenteives when costs, number of processes, number of services, and number of case (numerator of episode-of-care payment) are reduced and the number of episodes of care (payment unit) are expanded. And under full capitation, there are incentives when costs, number of processes, number of services, number of case, number of episodes of care, and number of conditions (numerator of full capitation) are reduced. In the case of full capitation, incentive points disperse to each component. Therefore, under full capitation, the incentive for LOS decrease is relatively weak compared with the episode-of-care payment system. The incentive for LOS decrease is not stronger in a larger payment unit system. The incentive is strongest under a DRG system.

In contrast, although KDPC is a per-diem based payment system, there is also incentive to decrease LOS under KDPC because its fee schedule is designed to provide more incentives during the early admission period. Compared to DRG, the incentive scale of KDPC is relatively small due to the FFS component. Therefore, the incentive for LOS decrease is not as strong for KDPC compared with DRG. However, KDPC may be sufficient for reducing LOS comprehensively in Korea, if LOS reduction is not the sole purpose for a payment system change.

4. Limitations

This study has several limitations. First, case hospitals included only public (and quasi-public) hospitals and control hospitals included only private hospitals. To minimize this problem, we used time-series analysis and sampled individuals using propensity score matching.

Second, we did not assess other factors that may be affected by the payment system change, such as costs or supplied services, due to lack of data. KDPC fee schedule includes more expensive services that are not included in the DRG schedule. Therefore, comparing claim costs only between KDPC and DRG is meaningless. However, LOS is an index that reflects medical service supply. Given that the aim of this study was to compare two bundled payment systems to provide evidence for the development of an appropriate reimbursement system, we think that LOS may be an appropriate and sufficient dependent variable for this study.

Finally, we analyzed only three surgical DRGs. More DRGs, especially medical DRGs, should be explored in future studies. The results of this study provide important evidence regarding the impact of payment system change on surgical DRGs.

VII. Conclusion

Average LOS for surgical DRG admissions increased following payment system change from DRG to KDPC. This LOS increase was observed specifically for complex procedure admissions and high severity cases. Although both payment systems are optimized to decrease LOS, incentives to reduce LOS are stronger under the DRG system than the KDPC system. Therefore, these findings suggest that incentives under the DRG lead to excessive LOS decrease in Korea.

Further increases in medical spending are expected due to the aging population, development of new medical technology, and higher standards of living. A provider-side cost-sharing payment system will be introduced in the future, because payment system changes have been met with low resistance by patients, and have introduced few burdens compared to other policy changes. We have already implemented DRG and KDPC, and the new payment system, which is based on these two bundled payment systems, is expected to be the next national payment system in Korea. A change in the national payment system should be undertaken with caution because enrollment of all medical institutions in the NHI is compulsory. We suggest that policymakers and stakeholders should focus on the development of an appropriate reimbursement system that focuses on more than cost containment, saving resources, or LOS reduction. More evidence and studies that focus on associations between payment systems and medical outcomes, resource spending, and quality will be needed to achieve this goal.

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Appendix

Appendix A.

S1. General characteristics of admissions before Propensity Score Matching

S2. General characteristics of admissions after Propensity Score Matching

Appendix B.

S3. Results of the segmented regression analysis with control for LOS of Appendectomy

S4. Results of the segmented regression analysis with control for LOS of Hernia procedures

S5. Results of the segmented regression analysis with control for LOS of Hemorrhoid procedures

Appendix C.

S6. Results of the segmented regression analysis with control for LOS by region subgroup

S7. Results of the segmented regression analysis with control for LOS by teaching status subgroup

Appendix D.

Statistical analysis

Appendix E.

S8. LOS change effects from results of CITS analysis

S9. LOS change effects from results of CITS analysis and trend adjusted triple DID by CCI subgroup

S10. LOS change effects from results of CITS analysis and trend adjusted triple DID by hospital type subgroup

S11. LOS change effects from results of CITS analysis and trend adjusted triple DID by region subgroup

S12. LOS change effects from results of CITS analysis and trend adjusted triple DID by teaching status subgroup

Appendix F.

S13. Predicted LOS change effects from results of the segmented regression analysis with control for LOS

S14. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by CCI subgroup

S15. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by hospital type subgroup

S16. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by region subgroup

S17. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by teaching status subgroup

Appendix G.

S 18. Results of the segmented regression analysis with control for LOS according to distributions

Appendix A. General characteristics of admissions before and after Propensity Score Matching

Table S1. General characteristics of admissions before Propensity Score Matching (n, %)

Variables	Before Intervention, 2007.1~2012.6				p-value	After Intervention, 2012.7~2014.6				p-value
	Case		Control			Case		Control		
Length of Stay (mean, SD)	5.42	2.47	3.63	1.92	<0.0001	5.15	2.33	3.38	1.86	<0.0001
Age (mean, SD)	41.2	21.7	41.2	15.6	0.0064	43.70	21.60	42.70	16.00	<0.0001
<10	1,546	5.6	7,007	2.0	<0.0001	403	4.1	1,824	1.5	<0.0001
10~19	4,511	16.4	19,146	5.4		1,417	14.4	6,436	5.1	
20~29	3,413	12.4	55,995	15.9		1,091	11.1	18,628	14.8	
30~39	3,779	13.7	80,962	23.0		1,300	13.2	27,854	22.2	
40~49	3,983	14.5	82,871	23.5		1,485	15.1	17,644	22.0	
50~59	3,630	13.2	60,649	17.2		1,528	15.6	23,833	19.0	
60~67	3,396	13.3	31,183	8.9		1,102	11.2	12,342	9.8	
>=70	3,284	11.9	14,303	4.1		1,496	15.2	6,991	5.6	
Sex					<0.0001					<0.0001
Male	17,374	63.1	199,262	56.6		6,225	62.4	72,886	58.0	
Female	10,168	36.9	152,854	43.4		3,597	36.6	52,666	42.0	
Principal diagnosis					<0.0001					<0.0001
Appendectomy	17,370	63.1	47,327	13.4		6,114	62.3	15,546	12.4	
Hernia procedures	4,380	15.9	20,479	5.8		1,609	16.4	8,684	6.9	
Hemorrhoid procedures	5,792	21.0	284,310	80.7		2,099	21.4	101,322	80.7	
Charson comorbidity index					<0.0001					<0.0001
0	13,221	48.0	162,924	46.3		4,195	42.7	54,686	43.6	
1	4,348	15.8	90,880	25.8		1,639	16.7	30,283	24.1	
2	3,555	12.9	56,447	16.0		1,458	14.8	22,702	18.1	
3	3,334	12.1	28,789	8.2		1,101	11.2	11,605	9.2	
>4	3,084	11.2	13,076	3.7		1,429	14.6	6,276	5.0	
Season					<0.0001					<0.0001
Spring	7,568	27.5	2,502	25.5		92,430	26.3	29,857	23.8	
Summer	7,276	26.4	2,635	26.8		84,073	23.9	31,244	24.9	
Autumn	5,737	20.8	2,218	22.6		71,741	20.4	28,811	23.0	
Winter	6,961	25.3	2,467	25.1		103,872	29.5	35,640	28.4	
Period					<0.0001					
2007.1~2008.6	7,615	27.7	95,177	27.0						
2008.7~2009.6	4,996	18.1	62,930	17.9						
2009.7~2010.6	5,191	18.9	63,215	18.0						
2010.7~2011.6	4,659	16.9	64,781	18.4						
2011.7~2012.6	5,081	18.5	66,013	18.8						
2012.7~2013.6						4,749	48.4	63,863	50.9	<0.0001
2013.7~2014.6						5,073	51.7	61,689	49.1	
Total	27,542	70.0	352,116	73.7		9,822	30.0	125,552	26.3	

Table S2. General characteristics of admissions after Propensity Score Matching (n, %)

Variables	Before Intervention, 2007.1~2012.6				p-value	After Intervention, 2012.7~2014.6				p-value
	Case		Control			Case		Control		
Length of Stay (mean, SD)	5.35	2.40	4.85	2.46	0.0003	5.06	2.23	4.62	2.6	<0.0001
Age (mean, SD)	40.2	21.2	39.6	21.0	<0.0001	42.7	21.2	43.7	21.1	<0.0001
<10	1,546	5.8	3,505	6.4	0.0002	754	4.2	403	4.2	<0.0001
10~19	4,511	16.8	9,082	16.7		2,531	14.0	1,417	14.9	
20~29	3,413	12.8	6,967	12.8		1,951	10.8	1,091	11.5	
30~39	3,779	14.1	7,704	14.2		2,245	12.4	1,300	13.7	
40~49	3,981	14.9	8,200	15.1		2,785	15.4	1,484	15.6	
50~59	3,620	13.5	7,464	13.7		3,113	17.2	1,523	16.0	
60~67	3,234	12.1	6,534	12.0		2,311	12.8	1,034	10.9	
>=70	2,661	10.0	4,935	9.1		2,399	13.3	1,243	13.1	
Sex					0.0002					<0.0001
Male	16,815	62.9	34,932	64.2		5,983	63.0	11,826	65.4	
Female	9,930	37.1	19,459	35.8		3,512	37.0	6,263	34.6	
Principal diagnosis					0.0460					0.0095
Appendectomy	16,573	62.0	34,185	62.9		5,787	61.0	10,682	59.1	
Hernia procedures	4,380	16.4	8,649	15.9		1,609	17.0	3,207	17.7	
Hemorrhoid procedures	5,792	21.7	11,557	21.3		2,099	22.0	4,200	23.2	
Charson comorbidity index					0.0061					<0.0001
0	13,221	49.4	27,221	50.1		4,195	44.2	7,472	41.3	
1	4,348	16.3	8,932	16.4		1,639	17.3	3,062	16.9	
2	3,555	13.3	7,334	13.5		1,458	15.4	3,050	16.9	
3	3,187	11.9	6,358	11.7		1,041	11.0	2,281	11.6	
>4	2,434	9.1	4,546	8.4		1,162	12.0	2,224	12.3	
Season					0.2007					0.9392
Spring	7,347	27.5	15,204	28.0		2,413	25.4	4,649	25.7	
Summer	7,058	26.4	14,015	25.8		2,559	27.0	4,836	26.7	
Autumn	5,553	20.8	11,412	21.0		2,154	22.7	4,121	22.8	
Winter	6,787	25.4	13,760	25.3		2,369	25.0	4,483	24.8	
Period					0.0004					
2007.1~2008.6	7,435	27.8	15,506	28.5						
2008.7~2009.6	4,855	18.2	10,194	18.7						
2009.7~2010.6	5,007	18.7	9,867	18.1						
2010.7~2011.6	4,513	16.9	9,330	17.2						
2011.7~2012.6	4,935	18.5	9,494	17.5						
2012.7~2013.6						4,589	48.3	8,865	49.0	0.2852
2013.7~2014.6						4,906	51.7	9,224	51.0	
Total	26,745	73.8	54,391	75.0		9,495	26.2	18,089	25.0	

Appendix B. Results of the segmented regression analysis of DRGs

Table S3. Results of the segmented regression analysis with control for LOS of Appendectomy

Parameter		Estimate	SE	95% Confidence Limits		p-value
Intercept b		5.551	0.535	4.503	6.598	<.0001
Baseline trend		-0.002	0.005	-0.012	0.008	0.672
Level change		0.037	0.074	-0.109	0.182	0.6222
Trend change		-0.004	0.009	-0.021	0.013	0.6151
Difference between Public and private		0.042	0.235	-0.419	0.502	0.8598
Baseline trend of difference between case and control		-0.005	0.004	-0.012	0.003	0.268
Level change of difference between case and control		-0.161	0.176	-0.506	0.184	0.3595
Trend change of difference between case and control		0.021	0.011	0.000	0.041	0.0496
Age		0.006	0.001	0.004	0.009	<.0001
Sex	Male	-0.113	0.016	-0.145	-0.081	<.0001
	Female	ref.				
Sub DRG	G081	3.167	0.139	2.894	3.439	<.0001
	G082	0.399	0.093	0.217	0.581	<.0001
	G083	1.972	0.270	1.443	2.501	<.0001
	G084	ref.				
Charlson comorbidity index	0	-0.905	0.101	-1.102	-0.708	<.0001
	1	-0.877	0.094	-1.062	-0.693	<.0001
	2	-0.752	0.087	-0.923	-0.580	<.0001
	3	-0.637	0.075	-0.784	-0.490	<.0001
	≥4	0.000	0.000	0.000	0.000	.
Hospital type	General	-0.079	0.325	-0.716	0.559	0.8083
	Hospital	ref.				
Hospital ownership	Public	0.091	0.336	-0.566	0.749	0.7860
	Corporation	0.055	0.263	-0.460	0.570	0.8340
	Private	ref.				
Teaching status	Teaching	0.474	0.187	0.107	0.841	0.0113
	Non-teaching	ref.				
Region	Urban	-0.046	0.235	-0.506	0.415	0.8461
	Rural	ref.				
Season	Spring	-0.062	0.024	-0.108	-0.016	0.0087
	Summer	-0.011	0.025	-0.059	0.038	0.6576
	Autumn	-0.032	0.032	-0.095	0.030	0.3099
	Winter	ref.				
Year	2007	-0.116	0.355	-0.811	0.580	0.7446
	2008	-0.140	0.293	-0.714	0.433	0.6316
	2009	-0.138	0.250	-0.628	0.352	0.5808
	2010	0.013	0.218	-0.415	0.441	0.9534
	2011	-0.012	0.181	-0.368	0.343	0.9454
	2012	-0.076	0.158	-0.385	0.234	0.6328
	2013	0.046	0.087	-0.125	0.217	0.5996
	2014	ref.				
Number of Bed		0.002	0.001	0.001	0.004	0.0006
Number of doctor		-0.004	0.001	-0.006	-0.002	<.0001
Number of Nurse		-0.005	0.002	-0.008	-0.002	0.0010

Table S4. Results of the segmented regression analysis with control for of Hernia procedures

Parameter		Estimate	SE	95% Confidence Limits		p-value
Intercept b		0.762	0.743	-0.695	2.219	0.3051
Baseline trend		-0.017	0.008	-0.033	-0.001	0.0376
Level change		-0.129	0.149	-0.421	0.163	0.3862
Trend change		0.012	0.013	-0.013	0.037	0.348
Difference between Public and private		-0.131	0.407	-0.928	0.666	0.7472
Baseline trend of difference between case and control		-0.015	0.005	-0.025	-0.005	0.0033
Level change of difference between case and control		0.091	0.218	-0.337	0.519	0.6772
Trend change of difference between case and control		0.040	0.014	0.011	0.068	0.0058
Age		0.055	0.006	0.044	0.066	<.0001
Sex	Male	-0.056	0.061	-0.175	0.062	0.3525
	Female	ref.				
Sub DRG	G095	-0.716	0.331	-1.365	-0.067	0.0306
	G096	-0.484	0.146	-0.771	-0.197	0.0009
	G097	-0.734	0.390	-1.499	0.031	0.0601
	G098	ref.				
Charlson comorbidity index	0	1.933	0.250	1.443	2.423	<.0001
	1	1.373	0.192	0.996	1.749	<.0001
	2	0.859	0.132	0.600	1.119	<.0001
	3	0.343	0.074	0.198	0.488	<.0001
	≥4	ref.				
Hospital type	General Hospital	0.033	0.412	-0.775	0.841	0.9362
	Hospital	ref.				
Hospital ownership	Public	1.982	0.543	0.919	3.045	0.0003
	Corporation	1.373	0.471	0.449	2.297	0.0036
	Private	ref.				
Teaching status	Teaching	0.703	0.392	-0.065	1.471	0.0728
	Non-teaching	ref.				
Region	Urban	0.037	0.300	-0.551	0.625	0.9012
	Rural	ref.				
Season	Spring	0.001	0.053	-0.102	0.104	0.9912
	Summer	-0.069	0.049	-0.165	0.027	0.1589
	Autumn	0.072	0.053	-0.032	0.176	0.1729
	Winter	ref.				
Year	2007	-0.550	0.533	-1.594	0.494	0.3017
	2008	-0.423	0.450	-1.305	0.460	0.3477
	2009	-0.334	0.381	-1.080	0.412	0.3806
	2010	-0.160	0.290	-0.729	0.409	0.5819
	2011	-0.136	0.228	-0.582	0.311	0.5516
	2012	-0.085	0.201	-0.479	0.309	0.6719
	2013	-0.006	0.123	-0.247	0.235	0.9609
	2014	ref.				
Number of Bed		0.003	0.001	0.001	0.005	0.0002
Number of doctor		-0.007	0.002	-0.011	-0.004	<.0001
Number of Nurse		-0.004	0.002	-0.009	0.000	0.0688

Table S5. Results of the segmented regression analysis with control for LOS of Anal procedures

Parameter		Estimate	SE	95% Confidence Limits		p-value
Intercept b		2.734	0.596	1.567	3.902	<.0001
Baseline trend		0.006	0.007	-0.007	0.019	0.3373
Level change		-0.011	0.091	-0.190	0.168	0.9071
Trend change		-0.012	0.009	-0.030	0.006	0.1837
Difference between Public and private		0.646	0.369	-0.077	1.369	0.0800
Baseline trend of difference between case and control		-0.010	0.006	-0.022	0.002	0.1027
Level change of difference between case and control		-0.196	0.285	-0.755	0.363	0.4914
Trend change of difference between case and control		0.022	0.017	-0.012	0.055	0.2072
Age		0.004	0.003	-0.002	0.010	0.2239
Sex	Male	-0.130	0.036	-0.201	-0.060	0.0003
	Female	ref.				
Sub DRG	G102	0.195	0.075	0.049	0.341	0.0089
	G104	-1.087	0.157	-1.395	-0.779	<.0001
	G105	-0.263	0.303	-0.857	0.330	0.3846
	G106	ref.				
Charlson comorbidity index	0	-0.314	0.141	-0.590	-0.038	0.0257
	1	-0.244	0.111	-0.461	-0.027	0.0277
	2	-0.195	0.096	-0.382	-0.008	0.0412
	3	-0.209	0.080	-0.366	-0.052	0.0092
	≥4	ref.				
Hospital type	General Hospital	-0.832	0.288	-1.397	-0.268	0.0039
	Hospital	ref.				
Hospital ownership	Public	1.555	0.444	0.684	2.426	0.0005
	Corporation	1.008	0.404	0.216	1.801	0.0126
	Private	ref.				
Teaching status	Teaching	0.950	0.333	0.298	1.603	0.0043
	Non-teaching	ref.				
Region	Urban	0.159	0.238	-0.307	0.626	0.5034
	Rural	ref.				
SEASON	Spring	-0.050	0.039	-0.127	0.027	0.2037
	Summer	-0.101	0.046	-0.190	-0.012	0.0269
	Autumn	-0.064	0.050	-0.163	0.034	0.2004
	Winter	ref.				
Year	2007	0.665	0.505	-0.325	1.654	0.1878
	2008	0.563	0.431	-0.282	1.409	0.1914
	2009	0.335	0.354	-0.358	1.029	0.3436
	2010	0.211	0.278	-0.335	0.757	0.4484
	2011	0.126	0.231	-0.327	0.580	0.5850
	2012	0.002	0.166	-0.324	0.328	0.9919
	2013	0.025	0.102	-0.175	0.224	0.8078
	2014	ref.				
Number of Bed		0.004	0.002	0.001	0.008	0.0239
Number of doctor		-0.003	0.005	-0.012	0.006	0.4741
Number of Nurse		-0.006	0.004	-0.014	0.002	0.1311

Appendix C. Results of region and teaching status sub-group analysis

Table S6. Results of the segmented regression analysis with control for LOS by region subgroup

		Level change of difference case and control			Trend change of difference case and control		
		Estimate	SE	p-value	Estimate	SE	p-value
Total	Urban	**-0.560**	0.180	0.0018	**0.045**	0.015	0.0017
	Rural	0.134	0.194	0.4895	0.017	0.013	0.2031
Appendectomy	Urban	-0.403	0.269	0.1344	**0.044**	0.012	0.0003
	Rural	0.053	0.227	0.8149	0.014	0.014	0.3429
Hernia procedures	Urban	-0.191	0.180	0.2878	**0.063**	0.025	0.0099
	Rural	0.000	0.271	0.9993	0.029	0.018	0.0965
Hemorrhoid procedures	Urban	**-1.717**	0.474	0.0003	0.009	0.038	0.8242
	Rural	0.324	0.287	0.2584	0.018	0.017	0.3101

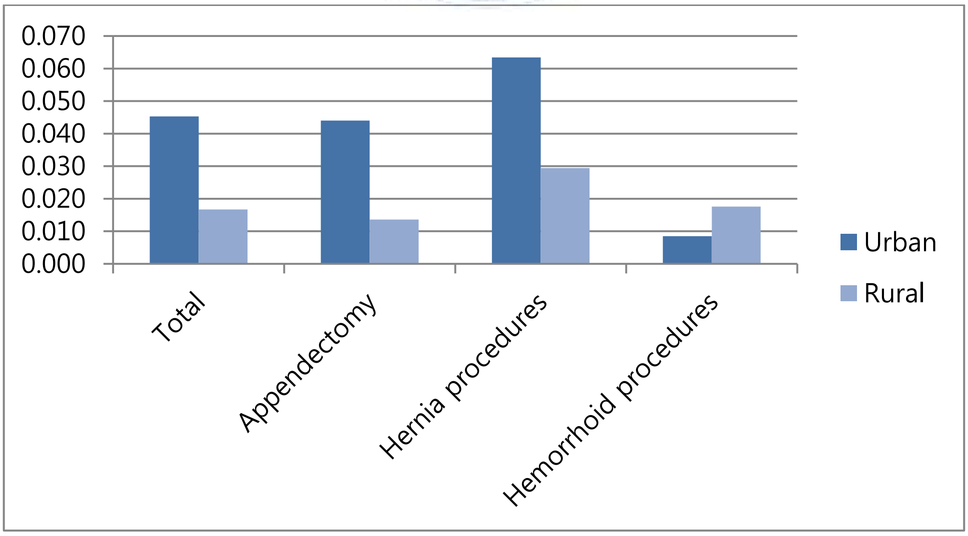

Figure S1. Results of the segmented regression analysis with control for LOS by region subgroup

Table S7. Results of the segmented regression analysis with control for LOS by Teaching status subgroup

		Level change of difference case and control			Trend change of difference case and control		
		Estimate	SE	p-value	Estimate	SE	p-value
Total	Teaching	**-0.542**	0.211	0.0103	0.018	0.016	0.2633
	Non-teaching	0.041	0.173	0.8128	**0.030**	0.012	0.0106
Appendectomy	Teaching	-0.527	0.272	0.0522	0.022	0.019	0.2405
	Non-teaching	0.006	0.214	0.9763	0.023	0.013	0.0857
Hernia procedures	Teaching	-0.380	0.265	0.1508	0.023	0.022	0.2981
	Non-teaching	0.258	0.259	0.3189	**0.055**	0.018	0.0021
Hemorrhoid procedures	Teaching	-0.527	0.966	0.5856	-0.063	0.047	0.1786
	Non-teaching	-0.082	0.286	0.7753	**0.039**	0.016	0.0129

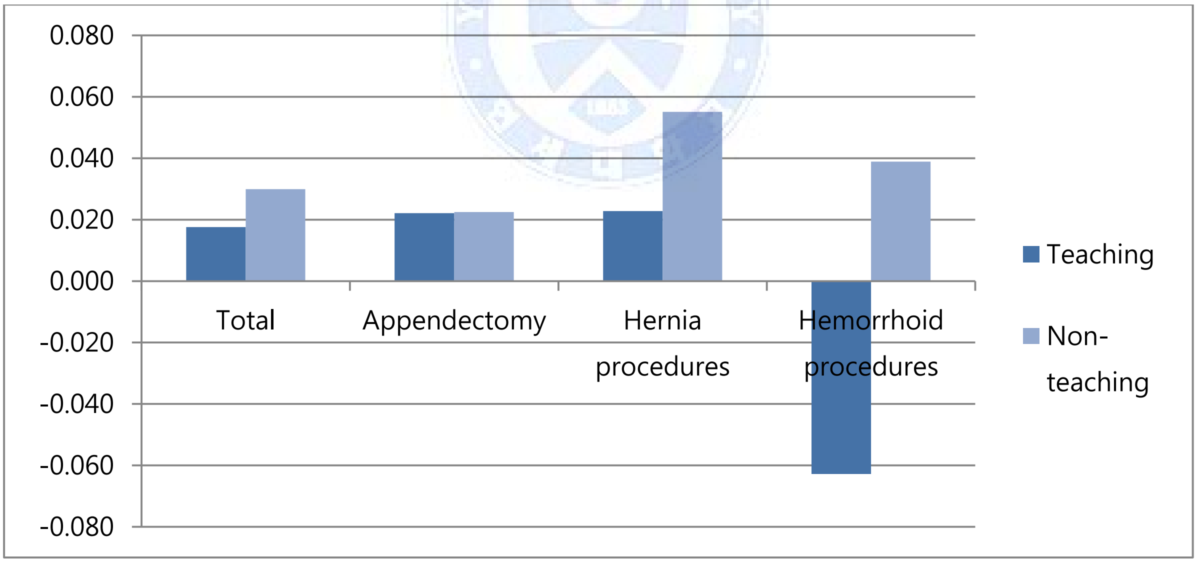

Figure S2. Results of the segmented regression analysis with control for LOS by teaching status subgroup

Appendix D. Statistical method

Our CITS (trend adjusted DID) equation was in Equation S1:

$$Y_{it} = \alpha_0 + \beta_0 Case + \phi_0 time_t + \lambda_0 time_t \times Case_i + \alpha_1 time\ after\ 1\ year_t + \beta_1 Case \times time\ after\ 1 year_t + \alpha_2 time\ after\ 2 year_t + \beta_2 Case \times time\ after\ 2 year_t + \delta Season_t + \mu_{1it} Z_1 + \cdots + \mu_{pit} Z_p + e_{it} \cdots (S1)$$

Y_{ht}: Average length of stay for hospital *h* of month *t*

i: each patient

t: time period (month)

$time_t$: a continuous variable started in January 2007 by month

time after 1 $year_t$: a binary variable (1 from 2012.7 to 2013.6; 0 else)

time after 2 $year_t$: a binary variable (1 from 2013.7 to 2014.6; 0 else)

$Case_i$: a binary variable (0 Control hospitals; 1 Case hospitals)

$Season_t$: seasonality (spring, summer, autumn, winter)

$\mu_{pit} Z_p$: independent variables ($1 \cdots p$)

e_{it} = Random variation in length of stay across time within hospital (within hospital variation)

In equation S1, *β1* could be interpreted as average difference between LOS of admission paid by KDPC and LOS of admission paid by DRG in first year after KDPC implementation. Withal, *β2* presents average difference of them in second year after KDPC implementation.

And CITS with subgroup (trend adjusted triple DID) equation was in Equation S2:

$$Y_{it} = \alpha_0 + \beta_0 Case_i + \phi_0 time_t + \lambda_0 time_t \times Case_i + \alpha_1 time\ after\ 1\ year_t + \beta_1 Case \times time\ after\ 1 year_t + \alpha_2 time\ after\ 2 year_t + \beta_2 Case \times time\ after\ 2 year_t$$
$$+ \text{Subgroup}_i \times (\beta_3 Case_i + \phi_1 time_t + \lambda_1 time_t \times Case_i + \alpha_3 time\ after\ 1\ year_t + \beta_4 Case \times time\ after\ 1 year_t + \alpha_4 time\ after\ 2 year_t + \beta_5 Case * time\ after\ 2 year_t)$$
$$+ \delta Season_t + \mu_{1it} Z_1 + \cdots + \mu_{pit} Z_p + e_{it} \cdots (S2)$$

$Subgroup_i$: subgroup categories (0: reference; 1,2..)

In equation S2, *β4* could be interpreted as average difference of LOS difference (between case and control) among subgroup in first year after KDPC implementation. Withal, *β5* presents it in second year after KDPC implementation.

To estimate the effect of KDPC implementation at particular time point, like 12month, 24month, 36month and 48month after implementation, we used following equation S3.

$$Y_{it} = \beta_0 + \beta_1 time_t + \beta_2 KDPC\ implementation_t + \beta_3 time\ point\ after\ KDPC\ implementation_k$$
$$+ \beta_4 Case_i + \beta_5 time_t \times Case_i + \beta_6 KDPC\ implementation_t \times Case_i + \beta_7 time\ point\ after\ KDPC\ implementation_k \times Case_i$$
$$+ \beta_8 season_t + \mu_{1it} Z_1 + \cdots + \mu_{pit} Z_p + e_{ht} \cdots (S3)$$

$KDPC\ implementation_t$: a binary variable (0 before June 2012; 1 after July 2012)

$time\ after\ KDPC\ implementation_t$: a continuous variable started in July 2012

k: estimate time point

$time_t$: a continuous variable from January 2007 to June 2012. Else k

time point after KDPC implementation$_k$: a continuous variable that make k as 0 after July 2012

In the equation S3, $\beta 7$ presents predicted difference between LOS change of case and LOS change of control at particular time point from baseline trend.

Appendix E. CITS analysis and trend adjusted triple DID

Table S8. LOS change effects from results of CITS analysis

	Trend adjusted difference						Trend adjusted Difference in Difference		
	Case			Control					
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
12th month point									
Total	-0.046	0.154	0.7638	0.019	0.100	0.8490	0.044	0.226	0.8447
Appendectomy	-0.028	0.167	0.8679	0.026	0.131	0.8417	-0.028	0.271	0.9183
Hernia procedures	-0.397	0.338	0.2400	-0.018	0.245	0.9423	-0.066	0.390	0.8658
Hemorrhoid procedures	0.177	0.327	0.5890	0.059	0.162	0.7141	0.040	0.483	0.9346
24th month point									
Total	0.079	0.178	0.6567	-0.205	0.120	0.0881	0.491	0.288	0.0878
Appendectomy	0.030	0.227	0.8967	-0.163	0.185	0.3794	0.353	0.328	0.2809
Hernia procedures	-0.022	0.333	0.9477	-0.324	0.227	0.1530	0.652	0.425	0.1251
Hemorrhoid procedures	0.163	0.382	0.6708	-0.180	0.102	0.0771	0.479	0.574	0.4043
1yr average									
Total	-0.051	0.111	0.6479	-0.031	0.054	0.5697	0.030	0.170	0.8618
Appendectomy	-0.044	0.141	0.7531	0.021	0.073	0.7715	-0.029	0.193	0.8825
Hernia procedures	0.042	0.172	0.8095	-0.053	0.127	0.6799	0.265	0.228	0.2438
Hemorrhoid procedures	-0.140	0.215	0.5160	-0.075	0.068	0.2760	-0.090	0.334	0.7885
2yr average									
Total	0.101	0.150	0.5040	0.031	0.078	0.6910	0.280	0.241	0.2447
Appendectomy	0.078	0.205	0.7038	0.131	0.120	0.2732	0.137	0.276	0.6201
Hernia procedures	0.042	0.172	0.8095	0.095	0.159	0.5516	**0.768**	0.290	0.0082
Hemorrhoid procedures	-0.122	0.284	0.6673	-0.163	0.098	0.0959	0.184	0.467	0.6936
Part of Appendectomy*									
12th month point	0.170	0.106	0.1095	0.085	0.113	0.4557	0.280	0.172	0.1027
24th month point	0.181	0.195	0.3537	-0.098	0.131	0.4539	**0.644**	0.279	0.0209
1yr average	0.025	0.116	0.8274	-0.016	0.052	0.7646	0.212	0.142	0.1352
2yr average	0.058	0.162	0.7200	0.027	0.084	0.7493	**0.402**	0.199	0.0432

*Sub-DRG: R082, R084;
Adjusted age, sex, CCI, hospital type, hospital ownership, teaching status season, year, number of bed, number of doctor and number of nurse

Table S9. LOS change effects from results of CITS analysis and trend adjusted triple DID by CCI subgroup

	1yr average						2yr average					
	trend adjusted DID			trend adjusted Triple DID			trend adjusted DID			trend adjusted Triple DID		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Total												
CCI 0, 1	-0.048	0.166	0.7734	ref.			0.186	0.241	0.4386	ref.		
CCI 2, 3	-0.025	0.221	0.9090	0.072	0.146	0.6202	0.231	0.292	0.4298	0.041	0.203	0.8396
CCI ≥4	0.404	0.248	0.1037	**0.456**	0.222	0.0404	**0.939**	0.329	0.0043	**0.678**	0.300	0.0236
Appendectomy												
CCI 0, 1	-0.069	0.188	0.7143	ref.			0.118	0.275	0.6691			
CCI 2, 3	0.072	0.255	0.7778	0.155	0.177	0.3806	0.143	0.324	0.6582	0.007	0.227	0.9763
CCI ≥4	0.212	0.556	0.7030	0.250	0.550	0.6499	0.843	0.686	0.2191	0.494	0.690	0.4738
Hernia procedures												
CCI 0, 1	0.070	0.250	0.7806	ref.			**0.594**	0.258	0.0210	ref.		
CCI 2, 3	0.218	0.303	0.4710	0.195	0.259	0.4515	**0.753**	0.364	0.0384	0.329	0.326	0.3127
CCI ≥4	0.461	0.302	0.1269	0.477	0.291	0.1014	**0.887**	0.420	0.0345	0.573	0.346	0.0978
Hemorrhoid procedures												
CCI 0, 1	-0.092	0.324	0.7775	ref.			0.219	0.442	0.6203	ref.		
CCI 2, 3	-0.285	0.406	0.4830	0.001	0.253	0.9961	-0.088	0.582	0.8794	-0.197	0.381	0.6061
CCI ≥4	0.133	0.434	0.7599	0.530	0.355	0.1362	0.639	0.695	0.3581	0.501	0.501	0.3179
Part of Appendectomy												
CCI 0, 1	0.139	0.135	0.3018	ref.			**0.396**	0.197	0.0443	ref.		
CCI 2, 3	0.371	0.208	0.0744	0.225	0.1546	0.1461	0.289	0.263	0.2718	-0.038	0.215	0.859
CCI ≥4	0.755	0.535	0.1587	0.762	0.4503	0.0907	0.804	0.598	0.1787	0.755	0.592	0.202

*Sub-DRG: R082, R084

Table S10. LOS change effects from results of CITS analysis and trend adjusted triple DID by hospital type subgroup

	1yr average						2yr average					
	trend adjusted DID			trend adjusted Triple DID			trend adjusted DID			trend adjusted Triple DID		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Total												
General hospital	-0.177	0.383	0.6433	**0.832**	0.4075	0.0412	0.266	0.523	0.6109	0.904	0.4663	0.0525
Hospital	-0.417	0.452	0.3557	ref.			-0.184	0.294	0.5327	ref.		
Appendectomy												
General hospital	0.117	0.221	0.5949	0.664	0.4956	0.1807	**0.642**	0.296	0.0298	0.670	0.4527	0.1389
Hospital	-0.574	0.481	0.2328	ref.			-0.206	0.261	0.4307	ref.		
Hernia procedures												
General hospital	0.056	0.197	0.7763	0.327	0.5156	0.5261	0.254	0.283	0.3700	0.283	0.5956	0.6342
Hospital	1.651	1.303	0.2050	ref.			0.843	0.793	0.2881	ref.		
Hemorrhoid procedures												
General hospital	0.079	0.179	0.6600	**1.524**	0.5477	0.0054	0.367	0.254	0.1478	**1.661**	0.8378	0.0474
Hospital	**-1.183**	0.438	0.0069	ref.			-1.027	0.636	0.1059	ref.		

Table S11. LOS change effects from results of CITS analysis and trend adjusted triple DID by region subgroup

	1yr average						2yr average					
	trend adjusted DID			trend adjusted Triple DID			trend adjusted DID			trend adjusted Triple DID		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Total												
Urban	-0.330	0.212	0.1194	ref.			0.182	0.347	0.5999	ref.		
Rural	0.241	0.217	0.2669	0.516	0.295	0.0796	0.372	0.321	0.2460	0.164	0.462	0.7225
Appendectomy												
Urban	-0.147	0.295	0.6185	ref.			0.290	0.362	0.4233	ref.		
Rural	0.138	0.245	0.5746	0.224	0.367	0.5418	0.255	0.355	0.4732	-0.068	0.505	0.8937
Hernia procedures												
Urban	-0.097	0.163	0.5547	ref.			**1.008**	0.511	0.0486	ref.		
Rural	0.196	0.278	0.4821	0.082	0.364	0.8224	0.388	0.334	0.2465	-0.898	0.632	0.1555
Hemorrhoid procedures												
Urban	**-1.672**	0.556	0.0027	ref.			**-1.578**	0.770	0.0405	ref.		
Rural	0.418	0.305	0.1705	**2.147**	0.644	0.0009	0.604	0.436	0.1658	**2.326**	0.884	0.0085

Table S12. LOS change effects from results of CITS analysis and trend adjusted triple DID by Teaching status subgroup

	1yr average						2yr average					
	trend adjusted DID			trend adjusted Triple DID			trend adjusted DID			trend adjusted Triple DID		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Total												
Teaching	-0.434	0.254	0.0880	ref.			-0.270	0.409	0.5092	ref.		
Non-teaching	0.207	0.189	0.2737	0.607	0.320	0.0580	**0.502**	0.271	0.0637	0.751	0.483	0.1195
Appendectomy												
Teaching	-0.382	0.341	0.2630	ref.			-0.199	0.547	0.7156	ref.		
Non-teaching	0.142	0.218	0.5137	0.470	0.414	0.2566	0.345	0.301	0.2523	0.530	0.627	0.3975
Hernia procedures												
Teaching	-0.322	0.239	0.1779	ref.			0.070	0.357	0.8447	ref.		
Non-teaching	**0.527**	0.263	0.0450	0.738	0.377	0.0500	**1.167**	0.341	0.0006	**1.002**	0.506	0.0479
Hemorrhoid procedures												
Teaching	-1.073	0.975	0.2707	ref.			-1.103	1.161	0.3423	ref.		
Non-teaching	0.126	0.302	0.6754	1.052	1.055	0.3190	0.567	0.410	0.1668	1.668	1.358	0.2194

Appendix F. Predicted LOS change effects from results of the segmented regression analysis with control

Table S13. Predicted LOS change effects from results of the segmented regression analysis with control for LOS

	Trend adjusted difference						Trend adjusted Difference in Difference		
	Case			Control					
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
12th month point									
Total	0.210	0.175	0.2298	-0.193	0.110	0.0792	0.162	0.201	0.4210
Appendectomy	0.200	0.222	0.3691	-0.078	0.145	0.5883	0.065	0.229	0.7772
Hernia procedures	0.434	0.286	0.1300	0.123	0.213	0.5659	**0.525**	0.243	0.0306
Hemorrhoid procedures	0.037	0.296	0.8996	-0.193	0.110	0.0792	0.042	0.395	0.9150
24th month point									
Total	0.548	0.306	0.0736	-0.180	0.174	0.3013	0.465	0.287	0.1052
Appendectomy	0.504	0.380	0.1844	-0.184	0.273	0.5002	0.311	0.326	0.3391
Hernia procedures	1.043	0.579	0.0715	0.336	0.356	0.3451	**0.999**	0.358	0.0052
Hemorrhoid procedures	0.220	0.465	0.6357	-0.364	0.225	0.1056	0.302	0.564	0.5923
36th month point									
Total	0.886	0.449	0.0486	-0.262	0.265	0.3228	**0.769**	0.386	0.0460
Appendectomy	0.808	0.550	0.1413	-0.289	0.406	0.4763	0.558	0.437	0.2021
Hernia procedures	1.653	0.891	0.0636	0.549	0.515	0.2871	**1.473**	0.506	0.0036
Hemorrhoid procedures	0.403	0.656	0.5387	-0.535	0.348	0.1240	0.562	0.752	0.4549
48th month point									
Total	1.506	0.719	0.0361	-0.412	0.434	0.3431	**1.326**	0.576	0.0213
Appendectomy	1.367	0.869	0.1157	-0.482	0.654	0.4604	1.010	0.655	0.1233
Hernia procedures	2.771	1.474	0.0601	0.939	0.820	0.2522	**2.341**	0.803	0.0035
Hemorrhoid procedures	0.739	1.022	0.4698	-0.848	0.577	0.1414	1.039	1.114	0.3510
Part of Appendectomy*									
12th month point	0.187	0.148	0.2070	-0.018	0.110	0.8697	0.316	0.162	0.0515
24th month point	0.392	0.264	0.1374	-0.016	0.225	0.9435	**0.575**	0.236	0.0150
36th month point	0.597	0.398	0.1334	-0.014	0.345	0.9679	**0.834**	0.330	0.0115
48th month point	0.973	0.653	0.1365	-0.010	0.567	0.9858	**1.309**	0.517	0.0113

*Sub-DRG: R082, R084

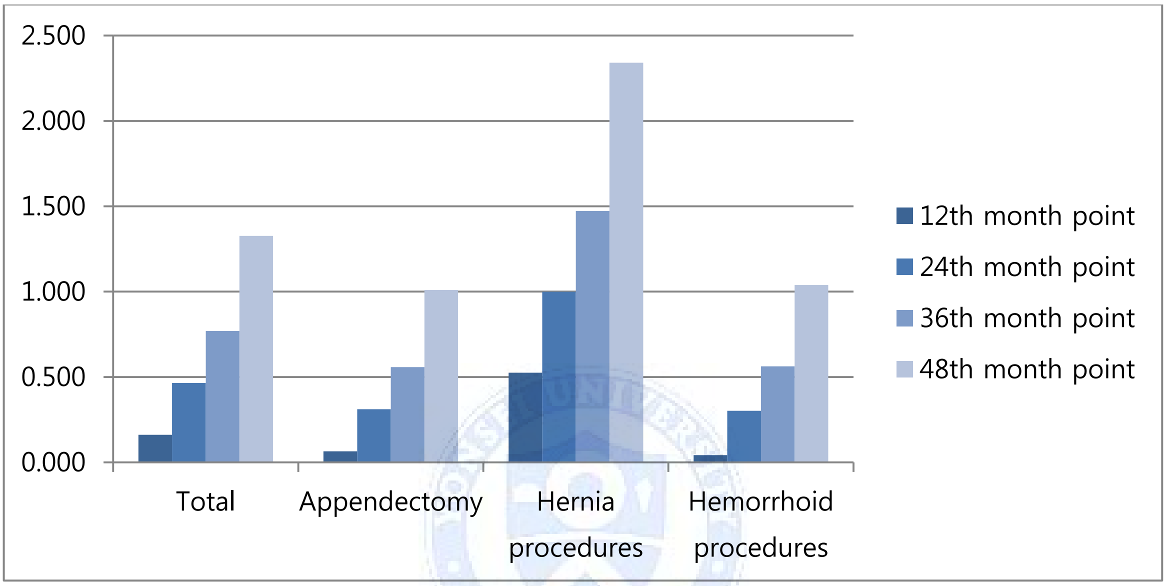

Figure S3. Predicted LOS change effects from results of the segmented regression analysis with control for LOS

Table S14. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by CCI subgroup

	12th month point			24th month point			36th month point			48th month point		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Total												
CCI 0, 1	0.073	0.198	0.7133	0.328	0.281	0.2426	0.584	0.376	0.1202	1.053	0.560	0.0602
CCI 2, 3	0.113	0.249	0.6508	0.426	0.349	0.2216	0.740	0.471	0.1161	1.315	0.715	0.0658
CCI ≥4	**0.710**	0.281	0.0114	**1.420**	0.414	0.0006	**2.129**	0.574	0.0002	**3.430**	0.890	0.0001
Appendectomy												
CCI 0, 1	0.031	0.225	0.8920	0.261	0.322	0.4178	0.491	0.432	0.2558	0.913	0.646	0.1576
CCI 2, 3	0.133	0.277	0.6313	0.352	0.397	0.3750	0.571	0.555	0.3037	0.972	0.876	0.2668
CCI ≥4	**0.829**	0.396	0.0362	1.494	0.786	0.0573	**2.415**	1.039	0.0201	**4.103**	1.572	0.0091
Hernia procedures												
CCI 0, 1	0.328	0.225	0.1439	**0.728**	0.316	0.0212	**1.128**	0.471	0.0167	**1.861**	0.797	0.0195
CCI 2, 3	0.518	0.312	0.0966	**1.107**	0.424	0.0090	**1.695**	0.590	0.0040	**2.773**	0.937	0.0031
CCI ≥4	**0.710**	0.341	0.0374	**1.221**	0.520	0.0188	**1.731**	0.738	0.0190	**2.667**	1.167	0.0223
Hemorrhoid procedures												
CCI 0, 1	0.056	0.378	0.8818	0.313	0.534	0.5581	0.570	0.711	0.4233	1.041	1.055	0.3239
CCI 2, 3	-0.195	0.482	0.6856	-0.049	0.682	0.9431	0.098	0.905	0.9140	0.366	1.338	0.7843
CCI ≥4	0.439	0.538	0.4144	1.234	0.879	0.1604	2.028	1.283	0.1139	3.484	2.064	0.0914

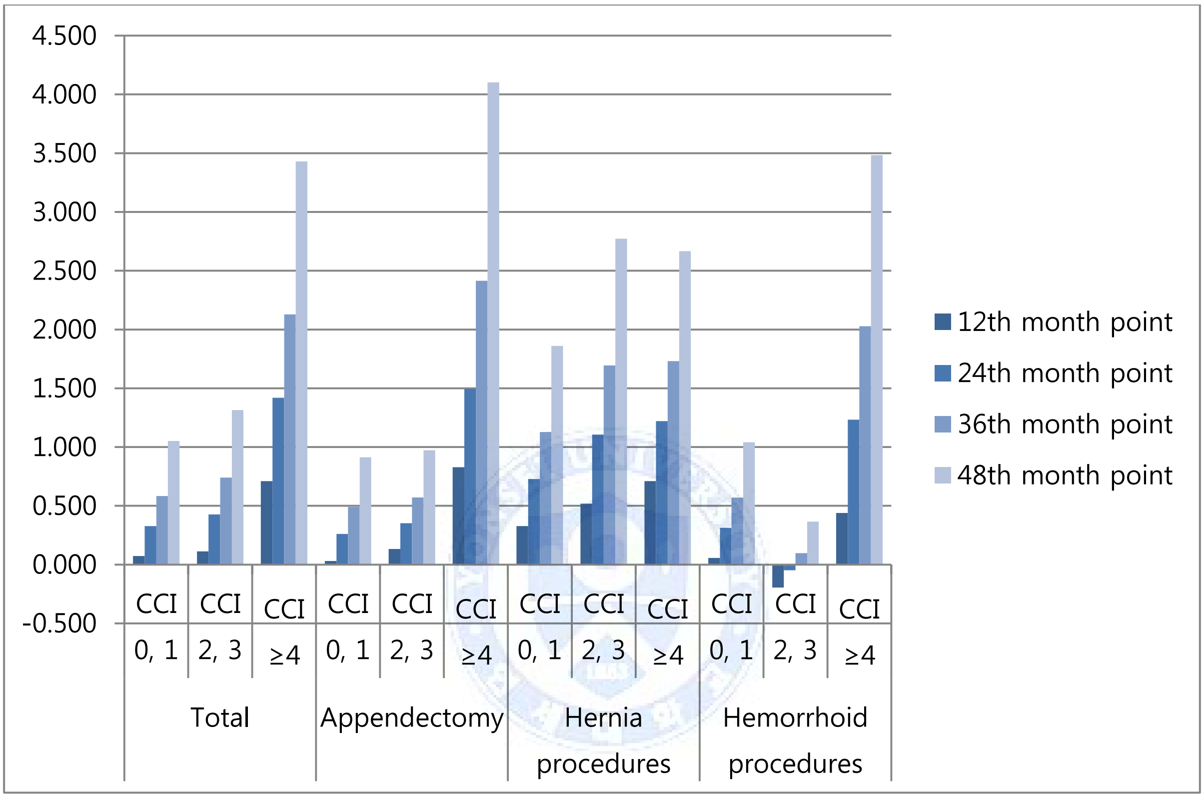

Figure S4. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by CCI subgroup

Table S15. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by hospital type subgroup

	12th month point			24th month point			36th month point			48th month point		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Total												
General hospital	0.232	0.210	0.2703	0.589	0.307	0.0550	**0.947**	0.420	0.0243	**1.602**	0.641	0.0125
Hospital	-0.322	0.339	0.3432	-0.240	0.439	0.5841	-0.159	0.639	0.8034	-0.010	1.079	0.9924
Appendectomy												
General hospital	0.165	0.232	0.4755	0.448	0.337	0.1843	0.730	0.462	0.1140	1.248	0.707	0.0773
Hospital	-0.400	0.370	0.2798	-0.108	0.355	0.7610	0.184	0.466	0.6928	0.720	0.809	0.3733
Hernia procedures												
General hospital	0.389	0.230	0.0904	**0.911**	0.363	0.0121	**1.432**	0.539	0.0079	**2.388**	0.888	0.0072
Hospital	1.214	1.108	0.2733	-0.286	1.127	0.7995	-1.786	1.245	0.1513	**-4.536**	1.637	0.0056
Hemorrhoid procedures												
General hospital	0.024	0.437	0.9555	0.386	0.611	0.5276	0.747	0.817	0.3603	1.409	1.224	0.2496
Hospital	**-1.132**	0.490	0.0208	-1.182	0.744	0.1122	-1.231	1.018	0.2265	-1.322	1.537	0.3896

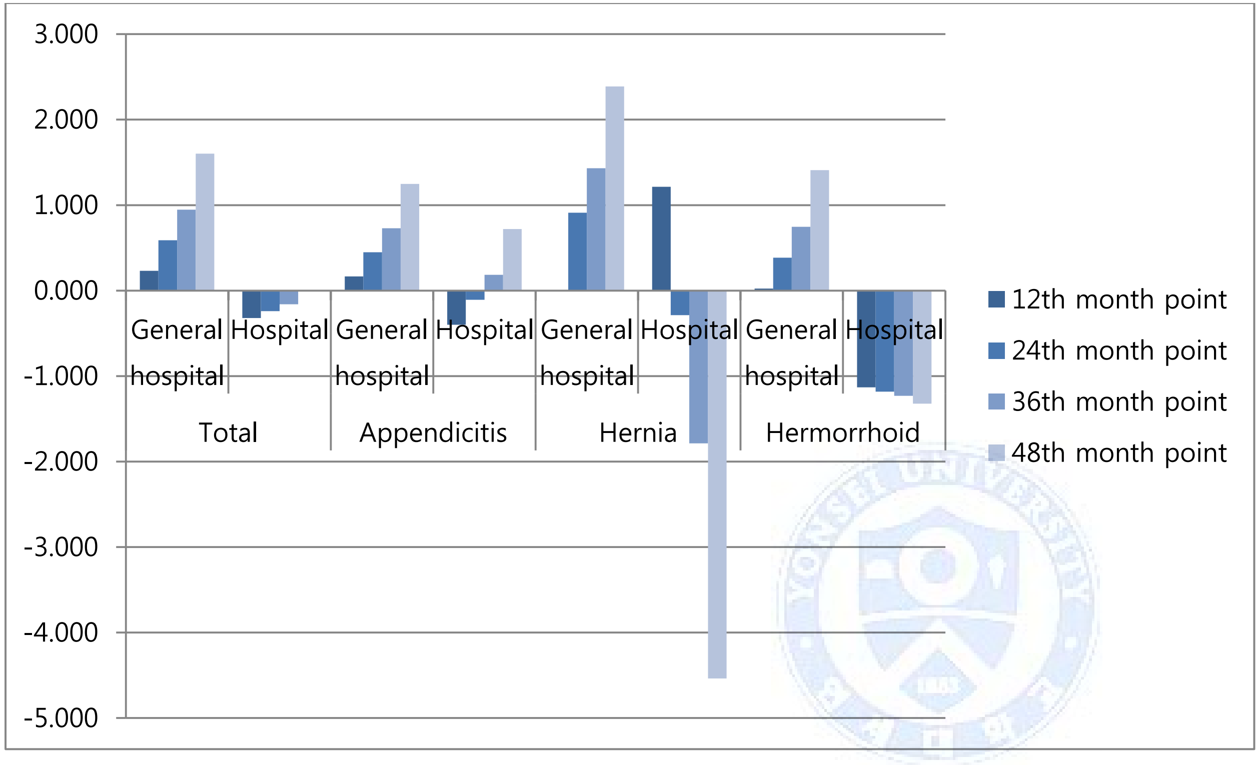

Figure S5. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by hospital type subgroup

Table S16. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by region subgroup

	12th month point			24th month point			36th month point			48th month point		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Total												
Urban	-0.070	0.271	0.7954	0.472	0.421	0.2621	1.014	0.585	0.0827	**2.009**	0.895	0.0248
Rural	0.316	0.263	0.2293	0.514	0.388	0.1853	0.713	0.531	0.1794	1.077	0.807	0.1819
Appendectomy												
Urban	0.081	0.321	0.8015	0.609	0.421	0.1481	**1.137**	0.542	0.0359	**2.105**	0.786	0.0074
Rural	0.203	0.291	0.4867	0.366	0.422	0.3858	0.529	0.574	0.3573	0.828	0.873	0.3431
Hernia procedures												
Urban	0.507	0.331	0.1259	**1.268**	0.601	0.0348	**2.029**	0.887	0.0221	**3.425**	1.421	0.0159
Rural	0.324	0.292	0.2678	0.677	0.430	0.1155	1.031	0.613	0.0925	0.016	0.016	0.3096
Hemorrhoid procedures												
Urban	**-1.623**	0.653	0.0129	-1.522	1.024	0.1372	-1.420	1.446	0.3261	-1.233	2.257	0.5848
Rural	0.518	0.350	0.1390	0.729	0.500	0.1443	0.941	0.681	0.1669	1.328	1.039	0.2013

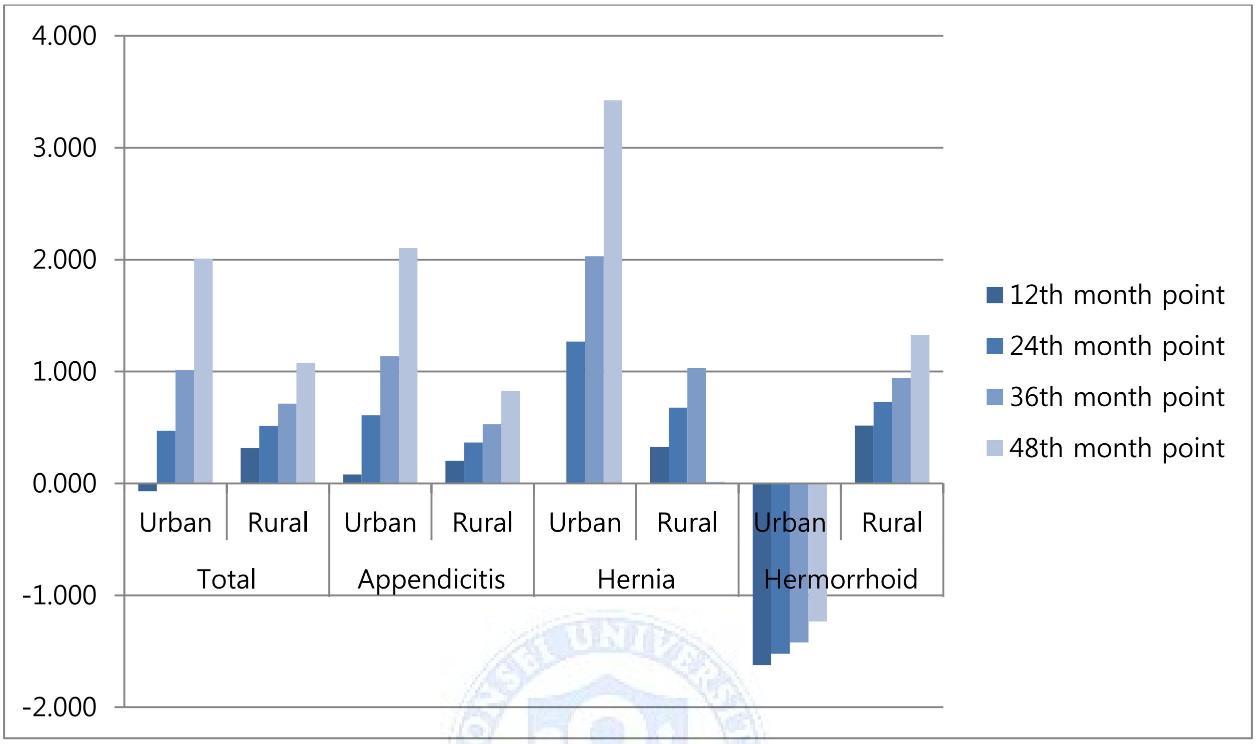

Figure S6. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by region subgroup

Table S17. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by teaching status subgroup

	12th month point			24th month point			36th month point			48th month point		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Total												
Teaching	-0.348	0.327	0.2872	-0.139	0.492	0.7770	0.069	0.669	0.9178	0.451	1.005	0.6535
Non-teaching	0.363	0.222	0.1014	**0.718**	0.329	0.0290	**1.073**	0.455	0.0183	**1.724**	0.701	0.0139
Appendectomy												
Teaching	-0.284	0.441	0.5190	-0.019	0.651	0.9771	0.247	0.869	0.7764	0.733	1.276	0.5655
Non-teaching	0.254	0.247	0.3029	0.525	0.353	0.1378	0.795	0.488	0.1036	1.290	0.758	0.0889
Hernia procedures												
Teaching	-0.129	0.254	0.6116	0.145	0.438	0.7407	0.419	0.676	0.5357	0.921	1.142	0.4200
Non-teaching	**0.864**	0.283	0.0023	**1.525**	0.428	0.0004	**2.187**	0.616	0.0004	**3.399**	0.989	0.0006
Hemorrhoid procedures												
Teaching	-1.218	1.001	0.2240	-1.971	1.296	0.1283	-2.725	1.727	0.1148	-4.106	2.647	0.1209
Non-teaching	0.346	0.344	0.3136	0.813	0.475	0.0868	**1.280**	0.635	0.0438	**2.136**	0.956	0.0254

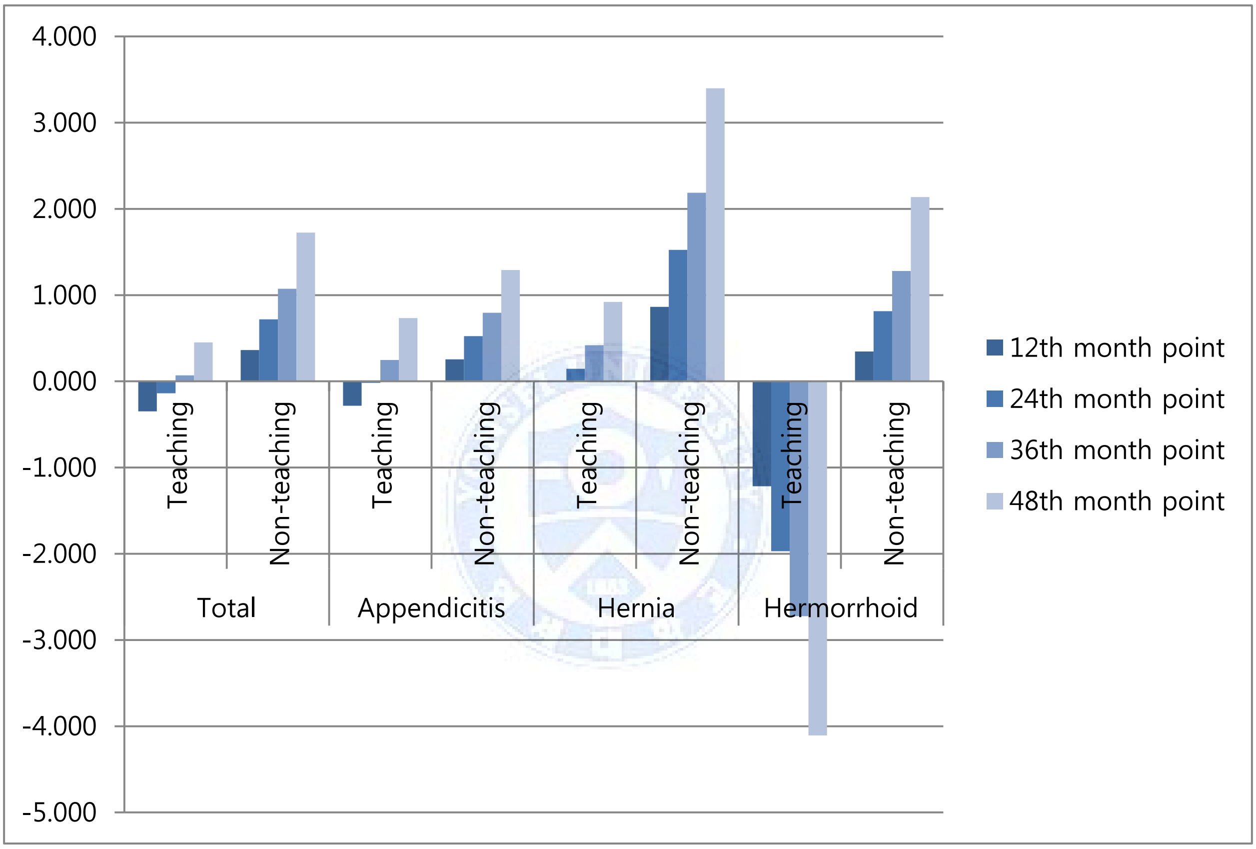

Figure S7. Predicted LOS change effects from results of the segmented regression analysis with control for LOS by teaching status subgroup

Table S18. Results of the segmented regression analysis with control for LOS according to distributions

Parameter	Normal		Negative binomial		Poisson	
	Estimate	p-value	Estimate	p-value	Estimate	p-value
Total						
Intercept b	**3.164**	<.0001	**2.808**	<.0001	**2.808**	<.0001
Baseline trend	-0.002	0.5827	-0.002	0.6016	-0.002	0.6016
Level change	-0.012	0.8450	-0.032	0.5957	-0.032	0.5957
Trend change	-0.004	0.5877	-0.003	0.6360	-0.003	0.6360
Difference between case and control	0.186	0.4872	0.245	0.3828	0.245	0.3828
Baseline trend of difference between case and control	**-0.007**	0.0412	**-0.007**	0.0324	**-0.007**	0.0324
Level change of difference between case and control	-0.117	0.4366	-0.073	0.6353	-0.073	0.6353
Trend change of difference between case and control	**0.025**	0.0055	**0.025**	0.0053	**0.025**	0.0053
Appendectomy						
Intercept b	**5.551**	<.0001	**5.416**	<.0001	**5.416**	<.0001
Baseline trend	-0.002	0.6720	-0.001	0.7403	-0.001	0.7403
Level change	0.037	0.6222	0.033	0.6066	0.033	0.6066
Trend change	-0.004	0.6151	-0.003	0.6950	-0.003	0.6950
Difference between case and control	0.042	0.8598	0.033	0.8839	0.033	0.8839
Baseline trend of difference between case and control	-0.005	0.2680	-0.004	0.2296	-0.004	0.2296
Level change of difference between case and control	-0.161	0.3595	-0.114	0.4806	-0.114	0.4806
Trend change of difference between case and control	**0.021**	0.0496	**0.021**	0.0313	**0.021**	0.0313
Hernia procedures						
Intercept b	0.762	0.3051	0.990	0.1103	0.990	0.1103
Baseline trend	**-0.017**	0.0376	**-0.014**	0.0433	**-0.014**	0.0433
Level change	-0.129	0.3862	-0.129	0.3635	-0.129	0.3635
Trend change	0.012	0.3480	0.005	0.6379	0.005	0.6379
Difference between case and control	-0.131	0.7472	-0.152	0.7230	-0.152	0.7230
Baseline trend of difference between case and control	**-0.015**	0.0033	**-0.013**	0.0094	**-0.013**	0.0094
Level change of difference between case and control	0.091	0.6772	0.080	0.7157	0.080	0.7157
Trend change of difference between case and control	**0.040**	0.0058	**0.039**	0.0030	**0.039**	0.0030
Hemorrhoid procedures						
Intercept b	**2.734**	<.0001	**2.733**	<.0001	**2.733**	<.0001
Baseline trend	0.006	0.3373	0.004	0.5004	0.004	0.5004
Level change	-0.011	0.9071	-0.025	0.7547	-0.025	0.7547
Trend change	-0.012	0.1837	-0.007	0.4309	-0.007	0.4309
Difference between case and control	0.646	0.0800	**0.712**	0.0398	**0.712**	0.0398
Baseline trend of difference between case and control	-0.010	0.1027	-0.010	0.1120	-0.010	0.1120
Level change of difference between case and control	-0.196	0.4914	-0.130	0.6509	-0.130	0.6509
Trend change of difference between case and control	0.022	0.2072	0.023	0.1796	0.023	0.1796

Korean Abstract

포괄지불제도의 변화가 외과 입원 환자의 재원일수에 미친 영향

- 포괄수가제에서 신포괄수가제로의 변화를 중심으로

서론: 지불제도는 공급자의 행태에 영향을 끼쳐, 의료비를 조절하는 수단으로 쓰인다. 한국에서는 2002년 7개 질병군에 대해 선택적으로 포괄수가제를 시행하였으며, 2013년 7월부터 해당 질병군에 대해 전면 시행하였다. 한편 신포괄수가제는 2012년 7월부터 지역거점 공공병원과 보험자병원에서 550개 질병군에 대해 시행하고 있다.

연구목적: 이 연구의 목적은 신포괄수가제의 시행이 외과 질병군 입원환자의 재원일수에 미친 영향을 평가하고, 이를 통해 적절한 지불 제도 개발을 위한 근거를 제시하는 것이다.

연구방법: 2007년 1월부터 2012년 6월까지 포괄수가제를 시행하다가 2012년 7월부터 2014년 6월까지 신포괄수가제를 시행한 병원에서 외과계 질병군인 맹장수술, 탈장수술, 항문수술로 입원한 36,240건을 실험군으로 선정하였으며, 2007년 1월부터 2014년 6월까지 지속적으로 포괄수가제를 시행한 병원과 종합병원에 동일 질병군으로 입원한 사람 중 Propensity Score Matching을 통해 72,480건을 대조군으로 선정하여 연구대상으로 포함하였다. Propensity Score Matching은 개인수준에서 나이, 성별, Charlson Comorbidity Index, 세부질병군 그리고 입원 날짜(월)을 매칭하여 이루어졌다. baseline의 재원일수 변화 경향과 제도 외적 효과를 제거하고 제도 도입으로 인한 영향만을 평가하기 위해 Segmented Regression Analysis in Interrupted Time Series Analysis 방법을 사용하였다.

연구결과: Segmented Regression Analysis in Interrupted Time Series Analysis 결과 포괄수가제에서 신포괄수가제 시행으로 시행 시점에서 재원일수가 0.007일 감소하였고, 재원일수의 증가 경향이 유의하게 나타났다 (0.025일/달). 이러한 재원일수 증가 경향은 맹장수술에서 0.021일/달 탈장수술에서

0.040일/달로 유의하였으며, 항문수술에서는 유의한 증가경향을 보이지 않았다.

Sub-group을 층화분석 한 결과, 중증도가 높은 그룹 일수록 더 가파른 재원일수 증가 경향을 보였으며, 이는 맹장수술과 탈장수술에서도 유의하게 보였다. 또, 종합병원에서 통계적으로 유의하게 재원일수 증가 경향을 보였고, 병원급에서는 유의한 변화를 보이지 않았다.

추가적으로 시행한 Comparative Interrupted Time Series analysis 분석 결과, 신포괄수가제 시행으로 인해 탈장수술에서 시행 2년째에 재원일수가 0.768일 증가하였다. 맹장수술 중 일부(복잡한 주진단의 제외한 경우)에 대해서 시행 2년째 재원일수가 0.402일 증가하였으며, 시행 24개월째 재원일수가 0.644일 증가하였다. Trend Adjusted Triple Difference-In-Difference analysis 분석 결과, 신포괄수가제 시행으로 대조군과의 차이에 대한 경향이 월 0.025일 증가하게 변하였다. 이러한 차이는 맹장수술(0.021일)과 탈장수술(0.040일)에서 있었으며 항문수술에서는 나타나지 않았다. Sub-group 분석에서 Trend Adjusted Triple Difference-In-Difference analysis 분석 결과, 신포괄수가제 시행으로 인해 중증도가 높은 그룹(CCI≥4)이 중증도가 낮은 그룹(CCI=0 ,1)보다 재원일수의 증가가 0.678일 더 있었다.

결론: 이 연구는 포괄수가제에서 신포괄수가제로의 지불제도 변화가 외과 입원환자의 재원일수에 미친 영향을 평가하였으며, 더 복잡한 수술이나 더 중증도가 높은 입원에서 재원일수가 증가 된 결과를 보였다. 두 포괄지불제도 모두 재원일수를 줄이는 인센티브를 갖지만, 포괄수가제가 신포괄수가제 보다 더 강력한 인센티브를 갖고, 이것이 한국 상황에서는 중증 환자 등의 경우에서 다소 지나칠 수 있다고 생각된다.

신의료기술의 발전과 고령화 등으로 지속적인 의료비 증가가 예상되는 가운데, 포괄 지불제도가 이에 대한 대안으로 검토되고 있지만, 한국은 단일 보험자로 단일 지불제도를 사용하므로 지불제도의 변경에 있어서 여러 가지 검토를 기반으로 한 신중한 선택과 개발이 있어야 할 것이다. 그러므로 지불제도의 변경에 있어서 의료자원 사용의 감소나 재원일수의 감소뿐 만 아니라 한국의 사정에 맞는 정확한 지불에 대한 고려를 해야 할 것을 제안한다.

핵심어: 포괄수가제, 신포괄수가제, 재원일수, 지불제도, 포괄지불제도, 외과계 질병군